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ELEMENTARY LECTURES
ON
CHEMISTRY
AND
NATURAL HISTORY.

CONTAINING
A METHODICAL ABRIDGEMENT
OF ALL THE
CHEMICAL KNOWLEDGE
ACQUIRED TO THE PRESENT TIME;
WITH
A COMPARATIVE VIEW OF THE DOCTRINE OF STAHL,
AND OF THAT OF SEVERAL MODERN CHEMISTS:
THE WHOLE FORMING A
COMPLETE COURSE OF THOSE TWO SCIENCES.

Tranſlated from the French of
M. FOURCROY,
Doctor of the Faculty of Medicine of Paris, and of the Royal
Society of Medicine.

By THOMAS ELLIOT.

WITH MANY ADDITIONS, NOTES, AND ILLUSTRATIONS,
BY THE TRANSLATOR.

IN TWO VOLUMES.

VOL. II.

BRISTOL ROYAL INFIRMARY

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ELEMENTARY LECTURES
ON
CHEMISTRY
AND
NATURAL HISTORY.

LECTURES XXXVI. XXXVII. and XXXVIII.

Species 11. IRON.

IRON, called *Mars* by the alchemiſts, is an imperfect metal of a white colour, blueiſh, and inclining to grey, diſpoſed in ſmall facets. It is ſuſceptible of a very ine poliſh and a great brilliancy. By its hardneſs and elaſticity it is capable of deſtroying the aggregation of all the other metals.

Iron has a ſmell, particularly when it is heated or rubbed: it alſo has a very remarkable ſtyptic taſte, which has a ſtrong effect upon the animal œconomy.

Iron is the lighteſt of the metallic ſubſtances except tin. A cubic foot of this metal, forged, weighs 580 pounds. It lengthens by the ſtroke of a hammer; but as it is very hard, and as it ſtiffens greatly, laminated leaves cannot be formed with it: its ductility in wire-drawing is much more remarkable; it is drawn into very fine threads, with which harpſichords are made. This property appears to depend on its tenacity: iron is indeed the moſt tenacious of all the metals except gold: a thread of iron, one-tenth of an inch in diameter, ſupports, without breaking, 450 pounds weight.

Pure iron has a cryſtalline form particular to itſelf. In the furnaces where this metal has been ſlowly cooled, it has been found in quadrangular pyramids, articulated and branched, formed of octagons laid on one another. We owe this obſervation to M. Grignon, forgemaſter at Bayard in Champagne. Beſides all the properties of which iron partakes in common with the other metallic ſubſtances, it exhibits ſtill three which are peculiar to itſelf alone: one is magnetiſm, or the property of being attracted by the magnet, and its becoming itſelf a very good magnet, either when it remains a long time in an elevated poſition, or in a direction from ſouth to north; or when it has ſerved for conducting the electric fire of thunder, as ſeveral facts atteſt; or when two pieces of iron are ſtrongly rubbed againſt one another. The ſecond property is, its taking fire and fuſing ſuddenly by the ſtroke of flint; a phenomenon to which the poets unanimouſly aſcribe the diſcovery of fire by our firſt parents. The third property which diſtinguiſhes iron, is, its being the only metallic ſubſtance which is found in plants and animals, a part of whoſe humours are coloured by it. It is even probable that theſe organic ſubſtances form this metal themſelves; for the plants raiſed in pure water contain it, which may be extracted from their aſhes.

Iron is a very copious metal in nature, being found, independently of what is contained in plants and animals, in almoſt all the coloured ſtones, in the bitumens, and in the greateſt number of the metallic ores. But we ſhall talk here only of the mineral ſubſtances which contain a great quantity of this metal, which may be ſmelted for its extraction. In theſe ores, which are very numerous, the iron is either in a metallic or in a calcined ſtate, or mineralized by different ſubſtances.

1. Native iron is diſtinguiſhed by its colour and malleability. It is very rare, and found only accidentally in iron mines. M. Margraaf found ſome of it in ridges at Ebenſteek in Saxony. Dr Pallas diſcovered ſome of it

in Siberia; and M. Adanſon ſays that it is common at Senegal.

2. Iron is very often, in the ſtate of ruſt, more or leſs calcined. It then forms the bog iron ores. It is diſtinguiſhed into rich and poor iron, fuſible and dry iron. The rich is iron only in a ſmall degree ruſty, and containing only a very ſmall quantity of earth. The fuſible iron fuſes eaſily, and is of a good quality: the metal is combined only with ſeveral ſtones of eaſy fuſion. The dry iron is more calcined, and intermixed with very refractory ſubſtances. All the bog-iron is diſpoſed generally in beds, in the ſame manner as ſtones are; and it has the appearance of having been depoſited by water. It is formed often into kinds of helmets or ſpherical bodies, flattened and irregular. It is not rare to find in it organic ſubſtances, ſuch as wood, leaves, barks, ſhells, changed into iron. It is neceſſary to obſerve, that organized ſubſtances are never found converted into any other metal but iron; and it appears that this converſion greatly depends upon the analogy which ſubſiſts between this metal and organic ſubſtances. In the wood of Boulogne, near Auteuil, there is a mine of bog iron, in which the vegetable ſubſtances change into iron almoſt before our eyes.

3. The eagle-ſtone, or ætites, is a variety of the bog-iron. Theſe ſtones are of different forms, commonly oval or polygonal, formed of concentric layers depoſited around a nucleus, which is frequently moveable in the centre of the ſtone. This ſtone has received its name from the belief that eagles depoſite it in their neſts, and that it has the property of facilitating their hatching: hence it has been concluded, that it acted ſtrongly upon the fœtus contained in its mother's womb; and ſome authors have even aſſerted, that it was poſſible to expedite the delivery of a woman in labour, by the application of the eagle-ſtone to her, or to retard it by applying it to her arm.

4. The hematites is a kind of bog-iron, which ſeems

to be formed in the manner of ſtalactites. Its name comes from its colour, which is generally red or of a blood colour; although, however, this colour varies. The hematites is compoſed generally of layers, which cover one another, and are themſelves formed of converging needles. On the external part of the ore are many tubercles or nipples. The hematites is diſtinguiſhed not only by the colour, but alſo by the form. Of this kind is the hematites in needles which is found in Lorrain, and the nippled hematites which is in the form of raiſin-ſtalks, or the botryoid hematites. Theſe ores are found very often along with bog-iron.

5. The magnet is only a bog-ore of iron. It is known by its property of attracting iron-filings. It is found in Auvergne, in Spain, in the Bay of Biſcay. The varieties of it are diſtinguiſhed by the colour.

6. The emerald, ſmyris, is a grey or reddiſh ore of iron, which ſeveral mineralogiſts take for a kind of hematites. It is very hard and refractory; there is great abundance of it in the iſlands of Jerſey and Guernſey. In mills it is reduced to powder, which is uſed for the poliſhing of glaſs and of metals.

7. The ſparry iron is a calx of iron, combined with the chalky acid, and carried along by water. It is generally of a white colour: it is to be found, however, of all kinds of hues; of grey, yellow, and red. It is always diſpoſed in greater or leſs laminæ, ſemitranſparent like ſpar: it is very heavy, and often regularly cryſtallized: it is found in conſiderable quarries, mixed frequently with pyrites, like that of Allevard in Dauphiné; ſometimes with the grey ore of ſilver, like the iron of Baigorry; or with manganeſe, like that of Styrie. Some mineralogiſts think that this is a ſpar, in which the metallic calx has been depoſited. The ſparry iron is entirely decompoſed, without addition, in cloſe veſſels, and gives over the chalky acid. Some iron remains in a black powder, which is very readily attracted by the magnet, and which fuſes eaſily with a ſtrong fire.

8. Nature alſo preſents iron in a ſaline ſtate, united with the vitriolic acid, forming martial vitriol or green copperas. This vitriol is found in the galleries of the mines of iron, particularly of thoſe which contain pyrites. It is found ſometimes in green cryſtals, or in the form of beautiful ſtalactites; at other times it is not ſo pure, and has ſuffered ſome alteration. If it has loſt only the water of its cryſtallization, it is of a whitiſh or greyiſh colour: it is called *ſori*. When it has undergone a little ſtronger calcination, it is yellow, and called *miſſy*. If the calcination has been ſo ſtrong as to carry off a conſiderable portion of the acid, the vitriol will be red, and called *colcothar* or *natural chalcite;* when mixed with ſome inflammable matter, it is called *melanteri*, on account of its black colour. All theſe different matters have received the name of *inkſtones*, on account of their property of making ink like vitriol of iron.

9. Iron is found frequently united with ſulphur: it then forms martial vitriol. This kind of ore has received the name of *pyrites*, becauſe it is ſo hard as to give many ſparks when it is ſtruck with ſteel. The martial pyrites are commonly in ſmall round, ſometimes regular, maſſes; for the moſt part, they are ſpherical, cubic, or twelve-ſided. Their form is very various; as is evident from reading the Pyritology of Kunckel. Externally ſome are brown, and of the colour of iron; others are yellow, and reſemble ores of copper, even at their ſurface: internally all of them are yellow, and ſeemingly coppery; and are formed for the moſt part of needles or pyramids of ſeveral ſides, whoſe tops converge to a common centre. Generally the pyrites are found in the neighbourhood of iron mines, and diſperſed through the clays and in coal pits: the upper layer of the latter conſiſts almoſt always of pyrites. All the pyrites are eaſily decompoſed. A very weak degree of heat ſuffices to carry off their ſulphur. Almoſt all of them undergo alteration when expoſed to the air, and

parti-

particularly in a moiſt place: they ſwell, burſt, loſe their colour, and are covered with a greeniſh white effloreſcence, which is only ſome martial vitriol. It ſeems that this alteration, called *vitrioliſation of the pyrites*, depends upon the united action of the air and water upon the ſulphur. There is formed ſome vitriolic acid, which diſſolves the iron, and is raiſed above the pyrites, like a kind of vegetation, by gradually removing the ſmall pyramids which compoſe this mineral. All the pyrites do not equally effloreſce. The globular pyrites, whoſe colour is very pale, and whoſe texture is not very cloſe, are very quickly vitrioliſed. Thoſe which are of a brilliant yellow, of a coppery colour, and are formed of ſmall laminæ cloſely adhering to one another, effloreſce but very difficultly, and ought to be carefully diſtinguiſhed from the firſt, ſince they differ from them in their colour, form, texture, and properties.

10. Iron is found combined alſo with arſenic. The ores of iron, combined with arſenic, are called *wolfram* or *ſpuma lupi*: they are of a violet colour, more or leſs, or red or blackiſh, very much reſembling that of the ores of tin, to which they approach alſo in their conſiderable weight. The arſenic may be ſeparated from it by roaſting. They are diſtinguiſhed from the true arſenical pyrites or miſpikel by the colour. This laſt is white, frequently cryſtalliſed in thick cubes, and contains but very little iron. The other reſembles the ore of tin; and ſeveral mineralogiſts have thought that it contained ſome of it. The wolfram is found in Franche Compté, in Voſges, in Saxony, and other places.

11. Black iron is known by its colour, by the property which it poſſeſſes of being attracted by the magnet, and of being quite ſoluble in the acids. This iron is ſometimes cryſtalliſed in form of polygons or in rounded laminæ, and preſents very brilliantly the various colours of the rainbow: of this ſort is that of the Elbe. This iron forms a conſiderable mountain, which is ſmelted in the open air. The ore of Sweden is alſo

black iron, but is not cryſtalliſed: it is in maſſes more or leſs ſolid, mixed with ſome quartz, ſpar, aſbeſtus, &c. It is often ſo hard as to receive a poliſh, and its ſurface appears to be like a mirror. It has alſo got, as well as the preceding, the name of *ſpecular ore:* conſiderable quarries of it are to be found. This iron varies in the intenſity of its colour: there is ſome of it perfectly black, which the magnet readily attracts; ſome blueiſh, which is leſs attracted; and ſome grey, which is very little. The iron of Norway is alſo black iron; but it is generally in ſmall ſcales like mica, frequently mixed with grenate and ſchorl. Black iron aſſumes ſometimes the form of grains. It is alſo cryſtallized in cubes; which has cauſed it to be named by ſome naturaliſts, *galena of iron*, or *eiſeng lants.* When the ore of iron, in the form of mica, is of a black colour, it is called *eiſen-mann*, particularly if the ſcales are very large: when theſe ſcales are red, and when the powder which covers them is of the ſame colour, it is called *eiſen-ram.* The ore of iron in eight-ſided black cryſtals, very regular, and diſperſed in a kind of colubrine or hard ſteatite, which comes to us from Sweden, Corſe, and other places, ſeems to belong to this claſs of ores of iron. It is very brittle, and attracted by the magnet.

The ores of iron are eſſayed in the following manner: After they are reduced into powder, they are mixed with double their weight of pounded glaſs, and one part of calcined borax: the mixture is carefully rubbed; it is put into a crucible, and a little marine ſalt added; the crucible is covered, and the fire applied till it fuſes. When the whole is cooled very ſlowly, the malleable iron is generally found in a ſmall ſpherical button, frequently cryſtalliſed at its ſurface.

The treatment of the ores of iron varies according to the ſtate in which the metal is found. There are ores which have no need of any preparation before they are fuſed; others ought to be pounded and waſhed, ſometimes even roaſted, in order to be made more tender and fuſible.

The bog and ſparry iron are ſmelted in the ſame way, by fuſing them acroſs coals. The furnaces in which the iron is fuſed vary in height, which is from 12 to 15 feet. Their cavity repreſents two quadrilateral pyramids, which join by their baſe towards the middle of the furnace; this place bears the name of *etallage*. A hole is made at the bottom of the furnace, to give an exit to the fuſed metal: this hole, which is ſtopped with earth, anſwers to a triangular canal, hollowed in the ſand, and deſtined to receive the fuſed iron. Firſt ſome firebrands lighted are thrown into the bottom of the furnace, then charcoal, and after that the ore and ſome fuſing ſubſtances: for the moſt part theſe ſubſtances are calcareous ſtones, called *caſtine*, and ſome argillaceous ſtones called *arbuc*, ſometimes ſome quartz or flints: the ore, the ſtones, and charcoal, are thrown alternately into the furnace, care being taken to cover the whole with a layer of charcoal, which ought to reach the ſuperior opening of the furnace. The fuſion is effected by the aid of two bellows. The iron fuſes, being reduced by the charcoal. The ſtony matters which are added to the ore becoming fuſed and vitrefied, facilitate the fuſion of the iron, which begins at the top of the etallage of the furnace; the fuſed metal is collected at the bottom of the furnace, in the part called the *crucible*; it is made to run by the anterior opening of the furnace into the canal hollowed in the ſand: it forms what is called the *font*. After the iron, there paſſes a vitreous matter called *ſlag*: it is formed by the vitrification of the ſtones which had been added to facilitate the fuſion of the iron: it is of a green whitiſh or blue colour, which is communicated to it by a portion of a fuſed calx of iron. The font is brittle, and has not the ductility of iron. Metallurgiſts are not agreed [illegible] the cauſe of this property of the font Some ſuppoſe that it is owing to the preſence of a portion of ſlag; others aſcribe it to this, that the iron is not fully reduced, and contains a portion of calx. Brandt ſuppoſed that it was owing to arſenic, and M. Sage thinks that it is zinc which renders it brittle. M. Bucquet conſidered the font as an iron not properly reduced, which ſtill contains a portion of metallic calx interpoſed between its parts. The metallurgiſts diſtinguiſh ſeveral kinds of fonts, the white, the grey, the black, &c. They give the name of ſpeckled font to that which, upon a grey ſurface, has black ſtains. The white font is the worſt; it approaches to the character of the ſemimetals. The grey holds the middle place between the firſt and the black; which is the beſt, and furniſhes iron of a good quality.

The fuſed iron is carried to the refining furnace. This is a forge a little hollowed, in which a maſs of font is put, which is covered with a good quantity of charcoal. The fire is blown till the iron begin to ſoften. When it is in this ſtate, it is *baked* ſeveral times. This kneading makes it preſent more ſurface; ſo that the portion of iron, in the ſtate of a calx, may be reduced. The metal is ſeparated alſo from a portion of ſlags, which remain in it. It is then ſubjected to the hammer, in order to be reduced into bars. The hammering, by approximating the parts of the iron, facilitates the ſeparation of the little ſlag and of the portion of calx which it may ſtill contain; conſequently it finiſhes what the fuſion had been unable to do for want of being ſufficiently complete. The iron is heated and beat ſeveral times, till it be as perfect as we wiſh to have it. Forged iron is diſtinguiſhed into ſoft iron and hard iron or ſteel.

Steel is the beſt and hardeſt iron, of the moſt fine and compact grain. The qualities of ſoft iron very much approach to thoſe of ſteel: its grain, however, is leſs compact; and when it is broken by bending, it appears to be compoſed of filaments or fibres. This is what is called *nervous* or *tough iron*. But this appearance is produced only accidentally; for if the ſofteſt iron is broken clean, and with one ſtroke, it does not turn out of that tough appearance; whilſt by breaking the worſt iron with precaution, it may be made to appear ſo. It is rather more expedient to attend to the grain of the metal when we are to judge of its quality. The hard iron is more brittle; its grain is coarſe, and ſeems to be formed of ſcales: it is diſtinguiſhed into iron cracking with heat, and into iron cracking with cold. This diſtinction is founded upon experience; the cauſe of which is not well known. It is not uncommon to find, in the ſame bar, brittle iron, ſoft iron, and ſteel.

The ſteel formed by the forge is rarely perfect ſteel; beſides, it is in ſmall quantity. By art iron may be converted into ſteel. For this purpoſe ſhort iron bars are made uſe of: theſe are put into an earthen box full of a cement, compoſed generally of very combuſtible matters, as the ſoot of chimneys, or the charcoal of animal ſubſtances: to theſe are added frequently cinders, calcined bones, marine ſalt, or ſal ammoniac. The box being well filled, it is heated ten or twelve hours till the bars be very white and beginning to fuſe. In this operation the iron is purified and completely reduced by means of the combuſtible matters which ſurround it on all ſides. The portions which were not quite in a metallic ſtate are metallized. With reſpect to the ſaline and earthy matters which are added, what purpoſes they ſerve is not well underſtood. The ſteel prepared in this way is called *ſteel of cementation*. This ſeems to be the pureſt iron.

Steel may be converted into iron, if it is treated by cementation with dry matters, and particularly with calcareous matters and lime, which ſeem proper to calcine a part of it.

It is evident that all the preparations to which iron is ſubmitted, are neceſſary on account only of its being more difficultly fuſed, and of its being never perfectly purified by a ſingle fuſion.

The ores of iron, and particularly the black iron, like that of the Iſle of Elbe, contain ſo much of the metal, and ſo little altered, that they do not require to be fuſed. It is only ſoftened among the coals in the refining furnace, and ſubmitted to the hammer. This is called the *Catalonian method:* it can be employed only in the caſe of ores, which contain few ſtrange matters ſuſceptible of converſion into ſlag.

The chemical properties of iron are very numerous; and for rightly underſtanding them, we muſt examine them in very pure ſteel.

Steel, expoſed to a fire incapable of making it red hot, varies in its colours; it whitens, becomes yellow, orange red, violet, and at length blue: it remains a long time of this laſt colour; but if it receives a ſtronger heat, it changes into a diſagreeable water-colour. Not a conſiderable heat turns ſteel red and bright: at firſt it is of a cherry-red, and at length it is white and ſhining, and it burns with a very ſenſible flame. It does not fuſe but with an extreme heat. If ſteel-filings are thrown into the middle of a fire, or even acroſs the flame of a candle, it ſuddenly takes fire, and produces very vivid ſparks: ſuch alſo are thoſe occaſioned by the flint of a firelock. The ſteel collected upon white paper is found to be fuſed, and to reſemble ſcoriæ or droſs. Ordinary iron, expoſed to the focus of M. de Trudaine's lens, ſuddenly emits burning ſparks. M. Macquer, who fuſed ſteel and iron with this lens, obſerved, that the ſteel was moſt fuſible, owing certainly to the metal's being pure and homogeneous. Fuſed iron, which cools ſlowly, aſſumes a particular cryſtalline form, as has been already obſerved. M. Mongez calls it a pyramid of three or four ſides. Steel, though very hard and refractory, is very eaſily calcined: as ſoon as it begins to redden, it combines with the air, and burns without an apparent flame. A bar of iron, kept red for a long time, preſents ſcales at its ſurface, which may be ſtruck off with a hammer: the metal in this caſe is only in part calcined, being attracted by the magnet. A more perfect calx of iron may be made, by expoſing ſome ſteel-filings under a muffle: it is converted into a powder of a reddiſh brown, not attracted by the magnet, called *crocus martis aſtringens*. This martial calx differs according to the ſtate of the iron, and to the degree of calcination which it undergoes. There are ſome croci martis of a yellow brown; others are of a cheſnut colour; and others again are of a finer red, and reſemble carmine. Crocus martis aſtringens, expoſed to a very ſtrong heat, fuſes into a blackiſh and porous glaſs. It is in part reduced by being heated ſlowly in cloſe veſſels: in its reduction it affords a certain quantity of chalky acid; which would ſeem to indicate, that the iron ſeizes upon this acid in its calcination, or rather that the pure air which is united to the metallic calx finds a principle with which it conſtitutes the chalky acid. In another place, I have offered a conjecture that this acid is a compound of pure air and inflammable gas. Were this conjecture demonſtrated, it would be eaſy to explain what paſſes here. It is known that iron, heated in a pneumato-chemical apparatus, affords inflammable gas. This fact has been demonſtrated by Dr Prieſtley. This gas, combined with the air which conſtitutes the calx of iron, forms aërial acid. Whatever be the theory of this ſingular experiment, we muſt agree that it is contrary to the new doctrine of calcination, but at the ſame time that it does not in a greater degree favour the theory of phlogiſton. The part of an hiſtorian which I have taken, requires that I ſhould repreſent what is contrary, as well as what is favourable, both to the theory of the gaſes and of Stahl.

Crocus martis aſtringens is very eaſily reduced by means of combuſtible matters. Upon mixing it with a little oil, and ſlightly heating it in a crucible, it becomes black and eaſily attracted by the magnet; by this proceſs may be made a very good ſpecies of martial æthiops.

The pureſt iron, expoſed to moiſt air, very ſoon parts with its metallic brillancy: it becomes covered with a powdery cruſt, yellowiſh, and brighter than the crocus martis aſtringens. This matter is called *ruſt*. Ordinary iron is much more ſubject to ruſt than ſteel is. The more it is divided, the more rapid is its alteration by the air. It is in this way that the medicine is prepared in pharmacy, which is called *crocus martis aperiens*. Steel-filings are expoſed to the air, and moiſtened with water: by this means it very quickly becomes ruſty. It is made ſtill more quickly with iron in the ſtate of an æthiops treated in the ſame way. In this alteration the metal agglutinates, and forms maſſes, which undergo porphyriſation before it is employed in medicine. We are not yet poſitively certain of the change produced in the iron by ruſt. Some of my own experiments lead me to conſider the ruſt, or the crocus martis aperiens, as a combination of iron and the chalky acid. I have diſtilled this ſaffron of mars in a pneumato-chemical apparatus, and I obtained from it a great quantity of chalky acid. The iron was changed into a black powder, eaſily attracted by the magnet. M. Joſſe, a Paris apothecary, has communicated a ſimilar proceſs to the Royal Society of Medicine, for obtaining readily martial æthiops. He recommends reddening crocus martis aperiens in a retort, to which a balloon with a ſmall hole in it is adapted without being luted: by this means the heat diſengages the chalky acid, which M. Joſſe allows to eſcape by the hole in the balloon, and the iron remains pure. By this means I have ſeveral times cryſtallized the cauſtic vegetable fixed alkali, with which I had wetted the ſides of the balloon adapted to the retort. By the tranſmiſſion of the aërial acid from the crocus martis aperiens upon the alkali, a kind of neutral ſalt, which with M. Bucquet I have named *tartar with the chalky acid*. I have made many other experiments upon the ruſt of iron, which I reſerve for a particular memoir: they all have convinced me, that that ſubſtance is a true neutral ſalt, formed by iron and the chalky acid. I think it ſhould be called *creta martialis*, to diſtinguiſh it from the true calx of this metal. This ſalt is abſolutely the ſame with what M. Bergman calls *terrum aëratum*. This theory was alſo adopted by M. Macquer; it very well explains why the iron readily ruſts in a humid and impure air; why this alteration is ſo quick and ſo deep in a place whoſe air is ſpoiled by the reſpiration of animals, by combuſtion, by the vapours of animal matters, as in ſtables, ſtalls, privies. Iron, of all the metallic ſubſtances, undergoes the greateſt alteration by the contact of the air: and this alteration is not confined to the ſurface; frequently very thick bars of iron are ruſted into their centre.

Water has a great action upon iron: it divides it, and even diſſolves a part of it, according to the experiments of M. Monnet. It takes up the more of it the purer the iron is, and the greater the quantity of air it contains. When iron is agitated ſome time in water, it is by little and little very minutely divided; and by pouring off the water, a little troubled, a very black and ſubtile powder of iron ſubſides, which has been called *martial æthiops of Lemery*. It is carefully dried with a gentle heat in a cloſe veſſel, as an alembic, leſt the contact of air ſhould ruſt it. The magnet attracts this martial æthiops very well: it is no more than iron reduced to a very fine powder. As this operation is very long and delicate, ſeveral chemiſts have found means to ſimplify it. M. Roeulle employed Count Garaye's mill, and by this means obtained a very fine æthiops in much leſs time than Lemery's proceſs requires. I think that of M. Joſſe might be ſubſtituted to it with advantage, which is much more expeditious. Several other proceſſes will be found afterwards as proper for the preparation of martial æthiops.

Steel in bars, heated to a certain degree, and ſuddenly plunged into cold water, aquires a very conſiderable hardneſs, and becomes very brittle. Theſe qualities are the more perceptible the ſtronger the heat and the colder the liquor was into which it was immerſed. This operation is called *tempering*. The hardneſs of the ſteel may be varied at pleaſure: it can be alſo ſoftened eaſily, by heating it to the ſame degree at which it was before tempering, and by leaving it to cool ſlowly. This effect ſeems to depend upon this, that the ſudden cooling of the ſteel, changes the diſpoſition of its parts, and prevents its cryſtallization. All the metals are ſuſceptible of acquiring hardneſs by being tempered: but this quality increaſes with the infuſibility of the metal: on this account iron poſſeſſes it in ſo eminent a degree.

Iron, in its metallic ſtate, does not unite with the earthy matters; but the calx of iron facilitates the vitrification of all the ſtones, and gives them a green colour.

Lime, magneſia, and the cauſtic fixed alkalis, have no remarkable action upon iron: it is weakly attacked by the volatile alkali; digeſted a few days, it becomes turbid, and allows a little æthiops to precipitate. This experiment of the academicians of Dijon proves, that the volatile alkali divides iron in the ſame way as water.

Iron is ſoluble in all the acids. M. Monnet has obſerved, that only boiling oil of vitriol acts upon iron: by diſtilling this mixture to dryneſs, flowers of ſulphur are found ſublimed in the retort, and a white vitriolic maſs ſoluble in part in water, but which cannot give cryſtals, becauſe the heat has decompoſed it. This acid, diluted with two parts of water, diſſolves the filings of iron very well in the cold: the ſolution is accompanied with the diſengagement of a great quantity of inflammable gas. A loud detonation may be produced by approaching a lighted candle to the mouth of the matraſs, after having been ſhut with the hand for ſome time. This gas burns with a reddiſh flame, and frequently gives very ſmall ſparks, reſembling thoſe of the filings of iron. M. Macquer thinks, that in this combination the vitriolic acid diſengages a great quantity of the phlogiſton of the iron, and that the inflammable gas belongs entirely to this metal. This opinion reſts upon this, that this gas may be diſengaged from it without any intermedium, by the ſole action of the fire: and likewiſe upon this, that M. de Laſſone has procured it from it by the action of the cauſtic, fixed, and volatile alkalis. The partiſans of the new doctrine ſuppoſe, that inflammable gas is a modification of ſulphur, and belongs to the vitriolic acid, as we have explained in treating of this acid. But the facts which I am going to mention favour more ſtrongly the doctrine of M. Macquer than the pneumatic theory. According as the vitriolic acid acts upon the iron, a portion of this metal is divided, and forms a black powder, taken by Stahl for ſome ſulphur, and which M. Monnet found to be ſome martial æthiops. It ſeems that this portion of iron ſuffered only a mechanical diviſion, reſembling that produced by the water. As ſoon as a part of the iron is united with a part of the acid, although this laſt be far from being ſaturated, the ſolution ſtops, and no longer acts upon the metal. M. Monnet, who made this obſervation, ſays, that upon pouring ſome water into the mixture, the action of the acid recommences. This phenomenon ariſes from the water of the ſpirit of vitriol being combined with the martial vitriol already formed; and the portion of the acid which is not ſaturated, requires to be diluted with a new quantity of water in order to diſſolve the iron. The vitriolic acid diſſolves more than the half of its weight of iron. This ſolution filtrated and evaporated by cooling, gives a tranſparent ſalt of a beautiful green colour cryſtallized in rhomboids. This is the martial vitriol or green copperas.

It is not worth while to make martial vitriol, ſince nature furniſhes abundance of it, and art with no difficulty extracts it from the martial pyrites. It is quite ſufficient to leave theſe pyrites expoſed to the air for ſome length of time: moiſture facilitates their decompoſition:

poſition: they become covered with a white effloreſcence, which requires merely ſolution and evaporation for the production of the martial vitriol. This decompoſition of the pyrites, according to Stahl, depends on the double affinities. Sulphur is compoſed of phlogiſton and vitriolic acid: neither water nor iron, ſeparately, is able to decompoſe it; but by the united action of theſe two bodies, the iron ſeizes upon the phlogiſton of the ſulphur, the acid of the ſulphur unites with the water, and diſſolves the metal; the pyrites, which are leſs ſuſceptible of efflореſcing, as thoſe which are brilliant, being roaſted, in order to diſſipate a portion of ſulphur which they contain, and afterwards expoſed to the air, effloreſce readily: the vitriol is ſeparated by waſhing. The ſolution of this ſalt depoſites afterwards a certain quantity of iron in the ſtate of ochre: it is only when this depoſition happens that the liquor is evaporated and cryſtalliſed. The partiſans of the pneumatic doctrine think, that in the vitrioliſation of pyrites, the ſulphur which is divided in them, as in the combinations with the alkaline ſubſtances, combines with a portion of pure air, and forms oil of vitriol; which diluted with the water of the atmoſphere in the ſtate of vapour, diſſolves and unites with the iron, at the ſame time producing heat. The neceſſity of the contact of the air to favour the effloreſcence of the pyrites, gives a certain degree of force to this opinion, as we have obſerved upon Combuſtion: but we ought not to forget, that the theory of M. Macquer unites theſe two doctrines, inflammable gas being diſengaged in the vitrioliſation in great quantity. We ſhall take more notice of this fact when we come to ſpeak of the combination of iron with ſulphur.

Martial vitriol has a green colour like that of the emerald, and a very ſtrong aſtringent taſte. It ſometimes reddens the ſyrup of violets; but this effect is not conſtant. Its cryſtals, according to the reſearches of Kunckel and M. Monnet, contain more than the half of their weight

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of water. If it is briſkly heated, martial vitriol liquefies, as all the ſoluble ſalts do, which are more ſoluble in hot than in cold water: by drying, it becomes of a whitiſh grey. If it is heated with a more violent fire, it allows a portion of its acid to eſcape in the form of ſulphureous gas, and it aſſumes a red colour; in this ſtate it is called *colcothar.* Vitriol, calcined to redneſs, very ſenſibly attracts humidity from the air, owing to a portion of vitriolic acid which it contains. Martial vitriol, diſtilled in a retort in a reverberatory furnace, at firſt gives over ſome water ſlightly acid, called *ros vitrioli.* The balloon is changed, to obtain ſeparately the oil of vitriol, which, when the fire is violent, paſſes over black, and emits a ſuffocating odour of volatile ſulphureous acid. Theſe circumſtances depend either, according to Stahl, upon a portion of phlogiſton, which it ſeparates from the iron; or, according to the doctrine of the gaſes, upon this, that it is deprived of a part of its air, which becomes fixed in the iron. Towards the end of the operation, the acid which diſtills aſſumes a concrete and cryſtalline form; it is called *glacial oil of vitriol.* This experiment, deſcribed by M. Hellot, did not ſucceed with M. Baumé; but its certainty is allowed by chemiſts. By diſtilling glacial oil of vitriol in a ſmall retort, ſome ſulphureous gas comes over, and the oil paſſes white and fluid. Should it owe its concrete ſtate to the preſence of this gas? It unites with water, cauſing a great noiſe and heat, leaving the ſulphureous gas to diſſipate. The reſiduum of the diſtilled martial vitriol is red, and called *colcothar:* by waſhing it with water, a white ſalt, little known, may be ſeparated, called *ſalt of colcothar,* or *fixed ſalt of vitriol.* An inſipid red earth remains, which is a pure calx of iron, called *ſweet earth of vitriol.* Martial vitriol, expoſed to the air, grows a little yellow, and is covered with ruſt. Cold water diſſolves half its weight of this ſalt; hot water more; but when it is ſaturated it appears turbid, by means of a greater or a leſs quantity of ochre. This ochre is ſeparated by filtration;

and the ſolution allowed to cool, produces rhomboidal cryſtals, of a pale and tranſparent green. The ſupernatant liquor ſubmitted to evaporation, affords a new ſet of cryſtals by cooling; and when cryſtalliſation is at an end, a mother-water remains of a blackiſh green or a brown yellow: this, when evaporated with a ſtrong heat, and allowed to cool, forms a ſoft unctuous maſs, which ſtrongly attracts the air's humidity. This maſs, completely dried, yields a powder of a greeniſh yellow. According to M. Monnet, the mother-water of martial vitriol contains ſome iron in the ſtate of a calx. This chemiſt convinced himſelf of this, by diſſolving immediately by means of heat a calx of iron in this acid: this ſolution is brown, and does not cryſtalliſe. The calx of iron may be ſeparated from its acid, not only by the aluminous earth, but alſo by copper and the filings of iron; which does not happen to perfect martial vitriol. A very abundant ſolution of perfect martial vitriol expoſed to the air, in time is changed into a vitriolic mother-water ſimilar to the preceding.

Martial vitriol may be decompoſed by lime and the alkalis. Lime-water poured into a ſolution of this ſalt, forms a precipitate in tufts of a deep olive green: a portion of this precipitate is rediſſolved in lime-water, and communicates to it a reddiſh colour. *Annis* 1777 and 1778, I read two memoirs to the Academy upon the martial precipitates, obtained by the mild or cauſtic alkalis; in which I accurately deſcribed the phenomena of theſe precipitations, and the ſtate of the iron in theſe different circumſtances. I ſhall give the prinpal reſults relative to vitriol. The cauſtic fixed alkali precipitates the ſolution of green vitriol in flocci of a deep green, which in part rediſſolve in the alkali, and form a kind of a martial tincture of a very beautiful red. When we add leſs of this alkali, the precipitate may be collected and obtained in a blackiſh æthiops, if we dry it rapidly and in cloſe veſſels. Without theſe two precautions, the iron very quickly ruſts, being divided and moiſt. The vegetable alkali, ſaturated with fixed air, forms a precipitate of a greeniſh white, which does not rediſſolve in the alkali: this difference is owing to the preſence of the chalky acid, which unites with the iron as it ſeparates from the alkali in its union with the vitriolic acid. The pure or cauſtic volatile alkali ſeparates from the ſolution of martial vitriol a green precipitate, ſo deep that it appears black, which does not rediſſolve in the volatile-alkali: we may by ſudden exſiccation, without the contact of air, obtain it black, and attractible by the magnet. The precipitate formed by the concrete volatile alkali, or by the volatile united with the chalky acid, is of a greeniſh grey: it rediſſolves in part in this ſalt, and communicates to it a red colour; which is the reverſe of what happens to the precipitations by the fixed alkali, ſince this laſt cauſtic ſalt very quickly diſſolves the martial precipitate; whilſt the ſame ſalt, united with the chalky acid, diſſolves it but with difficulty.

The vegetable aſtringent matters, as the gall-nut, ſumach, the rind of pomegranates, walnut-ſhells, Peruvian bark, Cyprian nuts, logwood, &c. have the property of precipitating martial vitriol black. This precipitate, which cannot but be taken for iron, is ſo extremely divided, that it remains ſuſpended in the liquor. When ſome gum arabic is added to the mixture, the ſuſpenſion of the precipitated iron is permanent, and there reſults a black liquor, known by the name of *ink*. It is not yet fully known what paſſes in this experiment. M. Macquer, M. Monnet, and the greateſt part of chemiſts, conſider the precipitate of the ink to be united with a principle in the gall-nut, which diſengages it from the acid. They ſeem induced to believe, that this principle is in an oily ſtate. The gentlemen of the Academy of Dijon, obſerving that this precipitation by the galls does not happen in an acid ſolution, and this precipitate diſappears by the addition of an acid, think, that the aſtringents direct their action to the vitriolic acid and precipitate the iron pure: becauſe the aſtringent principle has more affinity with this ſalt than the metal has. M. Gioanetti, phyſician at Turin, has made ſeveral experiments upon the iron precipitated from its ſolutions by aſtringents. From a view of his reſearches, given in his analyſis of the waters of St Vincent, that this metal is not attracted by the magnet; that it acquires this property when heated in a cloſe veſſel; that it diſſolves in the acids, but without efferveſcence; that the ſolutions are not blackened by the gall-nut, which ſhows that the iron is united with the aſtringent principle; and that it is in the ſtate of a kind of neutral ſalt. In the third volume of the Elements of Chemiſtry of the Academy of Dijon, a ſet of experiments is found upon the aſtringent principle of vegetables, which ſeem to aſſimilate this ſubſtance to the acids. Indeed, it reddens the blue colour of vegetables; it unites with the alkalis; it decompoſes the livers of ſulphur; it diſſolves and appears to neutralize the metals; it decompoſes all metallic ſolutions with particular phenomena; it is elevated in diſtillation, without loſing its action upon the metals; and it preſents a great number of other properties, which the order that we have laid down obliges us to paſs over *.

A phenomenon ſtill more difficult to explain than the action of the gall-nut upon martial vitriol, is the decompoſition of this ſalt by an alkali calcined with ox-blood.

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* We cannot do better than read and conſider the excellent reſearches of the academicians of Dijon upon the principle of aſtringency. They elucidate the labours of Meſſrs Macquer, Monnet, and Gioanette, upon this important ſubject. However, the ſubject is not yet exhauſted; and it requires a more complete examination, in particular to diſcover the nature of this ſingular principle, which is found in all aſtringent vegetable ſubſtances, and which ſeems to be ſoluble in a great number of menſtrua, ſuch as water, acids, alkalis, oils, ſpirit of wine, æther, &c. See *The Elements of Theoretical and Practical Chemiſtry, &c.* calculated to ſerve for the public courſes of the academy of Dijon, vol. iii. p. 403, to 421.

By this means we get a precipitate of a fine blue colour, inſoluble in the acids. This precipitate is called *Pruſſian* or *Berlin blue*, becauſe it was diſcovered in that city. Stahl relates, that a chemiſt, called *Dieſbach*, having borrowed of Dippel ſome fixed alkali to precipitate a ſolution of cochineal, mixed with a little alum and martial vitriol, this laſt gave him an alkali, upon which he had diſtilled his animal oil. This ſalt precipitated blue the ſolution of Dieſbach. Dippel inquired into the cauſe of this precipitate, and by a leſs complicated proceſs prepared Pruſſian blue, which was announced *anno* 1710 in the Berlin Tranſactions, but without any explanation of the operation. The chemiſts, thro' envy, laboured to ſucceed in the operation; and at laſt diſcovered it. It was not till *anno* 1724, that Mr Woodward publiſhed a proceſs for the preparation of this colouring ſubſtance in the Philoſophical Tranſactions. Four ounces of nitre fixed by tartar, and as much dried ox-blood, are mixed together: this mixture is calcined in a crucible till it be in the form of charcoal, and produces no more flame: it is waſhed with water in order to diſſolve all the ſaline matter, and the ſolution is called *phlogiſticated alkali:* this ley is concentrated by evaporation: then two ounces of martial vitriol and four of alum are diſſolved in a pint of water: the ſolution of theſe ſalts is mixed with the alkaline ley; a blueiſh depoſition takes place; the liquor is to be filtrated, and ſome marine acid is to be poured upon the precipitate. The precipitate then becomes of a more beautiful and of a deeper blue: it is dried with a gentle heat, or in the open air. Since Mr Woodward, many chemiſts have ſtudied both the preparation and the theory of Pruſſian blue. With regard to its preparation, it is now known, that a great number of ſubſtances are capable of giving the alkali the property of precipitating the iron blue. Geoffroy, in the Memoirs of the Academy *anno* 1725, has ſaid, that all the coals of animal matters poſſeſs this property. M. Baumé aſſerts, that the phlogiſticated alkali may be prepared alſo with the coals of vegetable ſubſtances by means of a more violent heat. M. Spielman has prepared it with the bitumens: Meſſrs Brandt and Monnet with ſoot. The manufacturers of Pruſſian blue are numerous; and each of them, it would appear, employ different matters for its preparation. M. Baunach informs us, that in Germany they uſe the claws of birds, and the horns and ſkin of oxen. All animal matters, however, do not appear to be proper for the phlogiſtication of the alkali. I have in vain attempted to prepare it with ox-bile, by a proceſs reſembling that which is employed with the blood. I obtained an alkali which precipitated vitriol only in a greeniſh white, and the precipitate diſſolved entirely in the marine acid.

Chemiſts have differed greatly about the theory of Pruſſian blue. Meſſ. Brown and Geoffroy conſidered it as the phlogiſticated part of the iron diſengaged by the blood-ley, and intermixed with the earth of alum. The Abbé Menon (firſt volume *des Savans Etrangers*) thought that it was the iron pure, and freed of every foreign ſubſtance by the phlogiſticated alkali. M. Macquer has refuted the opinions of theſe authors in a memoir, which has juſtly merited the name of Maſterpiece from all the chemiſts, and which is inſerted in the volume of the Academy for the year 1752. He thinks that the Pruſſian blue is iron only combined with an exceſs of phlogiſton, furniſhed by the phlogiſticated alkali which received it from the ox-blood. He obſerves, 1. That Pruſſian blue, expoſed to the fire, loſes its colour, and becomes ſimple iron. 2. That it is quite inſoluble in the acids, even the moſt powerful. 3. That the alkalis can diſſolve and become ſaturated with its colouring matter. An alkaline ley requires only to be heated upon it till the alkali acquires no more colour. This alkali, when ſaturated with the colouring matter of the Pruſſian blue, has loſt the moſt of its properties. It is no longer cauſtic; it does not efferveſce with the acids; it does not decompoſe the ſalts with earthy baſe, but it precipitates all the metallic ſalts; and it ſeems that this decompoſition happens in conſequence of a double affinity of the acid with the alkali, and of the colouring part united with the alkali. The alkali may thus deprive the twentieth of its weight of Pruſſian blue of its colouring principle: it then arrives at its point of ſaturation. The acids diſengage a ſmall quantity of a blue feculent matter from it; and it inſtantly precipitates martial vitriol in the form of perfect Pruſſian blue.

With regard to the alkali prepared in the ordinary way, M. Macquer obſerves, that it is far from being completely ſaturated with the colouring part, and that on this account it throws down at firſt a green precipitate from martial vitriol. The fact is, the portion of alkali which is ſaturated precipitates it blue; but the portion which is not ſaturated precipitates it in the ſtate of ochre, which renders the blue precipitate green by means of the mixture of this laſt colour with the yellow. According to this ingenious theory, the acid which is poured upon the precipitate ſerves to diſſolve and to increaſe the livelineſs of colour of the portion which is not in the ſtate of Pruſſian blue. The alum which is added to the ſolution of vitriol ſaturates the alkali, which is not charged with colouring matter; and the earth of this ſalt, depoſited with the Pruſſian blue, brightens its ſhady colours. As it is neceſſary to pour the acid upon the precipitate of the martial vitriol, in order to brighten the blue, this acid may be added to the alkali previous to its being uſed for precipitation; becauſe the acid, in ſaturating the portion of pure alkali, does not unite with that portion which is united with the colouring part; and thus it may inſtantly form a beautiful blue precipitate. The phlogiſticated alkali may likewiſe be ſaturated with this colouring principle, by digeſtion upon Pruſſian blue till it ceaſe to deprive it of colour. M. Macquer had given this alkali, ſaturated with acid, as a good teſt of the preſence of iron in the mineral waters: But M. Baumé has obſerved, that this liquor itſelf contained a certain quantity of Pruſſian blue; which circumſtance might lead us into miſtakes. He therefore propoſes ſetting it ſome time to digeſt along with a little vinegar, with a gentle heat, in order that it may depoſite all the blue matter which it contains. Such was the excellent treatiſe of M. Macquer upon the Pruſſian blue: but this celebrated chemiſt well perceived a deficiency, particularly with regard to the nature of the colouring ſubſtance. He could no be perſuaded that this was pure phlogiſton; becauſe, under that ſuppoſition, he did not conceive how iron, overcharged with this principle, entirely loſt at the ſame time the property of being attracted by the magnet, and of being ſoluble in the acids; properties, according to Stahl, owing to the preſence of phlogiſton in the metal. M. de Morveau is the firſt who, in his excellent diſſertation upon phlogiſton, has inquired into the nature of the colouring part of Pruſſian blue. From two gros of this compound, he extracted by diſtillation 22 grains of a yellow empyreumatic liquor, which effervefced with the mild alkalis, reddened blue paper; and of which Meſſ. Geoffroy and Macquer, although they alſo diſtilled Pruſſian plue, have made no mention.

M. Sage, anno 1772, ſent to the Electoral Academy of Mayence a memoir upon the phlogiſticated alkali, which he calls *animal ſalt*. M. Sage thinks that the fixed alkali, treated with blood, and ſaturated by digeſtion upon Pruſſian blue, in M. Macquer's way, is a neutral ſalt, formed by the animal acid and the fixed alkali. By inſenſible evaporation it gives cubic eight-ſided cryſtals, or priſms with four ſides, terminated by pyramids alſo with four ſides. This ſalt decrepitates upon coals: it fuſes with a violent heat into a ſemi-tranſparent maſs, ſoluble in water, and proper to make Pruſſian blue. M. Sage thinks that the acid which neutraliſes the alkali in this neutral ſalt, is the phoſphoric acid, becauſe the mixture of alkali and ox-blood, when urged with a ſtrong fire, fuſes, emits an acrid vapour, accompanied with white and brilliant ſparks; which, according to him, are only ſome burning phoſphorus. This opinion upon the acid of the Pruſſian alkali would have been corroborated, if, on the one ſide, by its diſtillation with charcoal, phoſphorus were obtained, which would alſo take place by making uſe of Pruſſian blue; and if, on the other part, Pruſſian blue were formed by the combination of the fuſible or phoſphoric ſalt with baſe of vegetable fixed alkali with a ſolution of iron. As M. Sage in his memoir has made no mention of ſuch experiments, his theory cannot be admitted.

Meſſieurs the chemiſts of the Academy of Dijon have adopted a part of this doctrine in their elements. They conſider the phlogiſticated ley as a ſolution of a neutral ſalt: they direct the cryſtalliſation of it by evaporation, inſtead of purifying it by means of vinegar in M. Baumé's way. This ſalt, ſay they, is very pure. When it is thrown upon fuſed nitre, a detonation takes place. They have ſaid nothing upon its decompoſitions and the nature of its principles; they called it *cryſtalliſed Pruſſian alkali.*

M. Bucquet, upon precipitating by means of the marine acid, and filtrating the ley prepared for the Pruſſian blue, obſerved that this alkali, though very clear, and apparently deprived of all the Pruſſian blue which it contained, allowed, however, a blue powder to precipitate. After having filtrated it more than twenty times in the ſpace of two years, in order to free it of the portion of Pruſſian blue, which precipitated after every filtration, he at laſt found that no more was produced by the ſolution of martial vitriol. I have had in my poſſeſſion, more than theſe five years, a ſmall portion of this ley: it has depoſited nothing theſe two years but a ſlight blueiſh covering upon the ſides of the veſſel which contained it, and it has preſerved a ſimilar colour. I have had occaſion to obſerve this phenomenon twice; ſince which I have underſtood that it was taken notice of by M. Bucquet in his courſes, and I believe that it is conſtant. M. le Duc de Chaulnes ſhowed to M. Macquer a phlogiſticated ley, which gave no Pruſſian blue when it was previouſly mixed with an acid. This chemiſt thinks that the cauſe of this is, that this ley was prepared in metal veſſels. M. Bucquet imagined, from the obſervation related above, 1. That the Pruſſian blue is all contained in the alkali employed to prepare it: 2. That the acids alone are able to precipitate it: 3. That when this alkali, in a longer or ſhorter time, has depoſited all the colouring part which it contains, it at length ceaſes to produce Pruſſian blue.

The Phyſical Journal, April 1778, contains obſervations upon Pruſſian blue, by M. Baunach apothecary at Metz, which greatly favour M. Bucquet's opinion. After having deſcribed the proceſs which is employed in the manufactures of Germany for its preparation, M. Baunach aſſures us, that the ley made in this manufacture by the fuſion of the alkali and of the charcoal of birds claws, and of oxens horns and ſkin, precipitates all the metals, and even the calcareous earth, blue. This alkali diſſolves the metals, after having precipitated them; and they may be ſeparated from it of a very beautiful blue colour by the marine acid. The ſingular facts announced in this Memoir; ſuch as the diſtillation of the Pruſſian blue, produced by this ley, which gives no oil nor volatile alkali; the ſolubility of the blue precipitate, formed by the marine acid when poured upon this ley, in the nitrous acid; the calcareous earth found diſſolved in this laſt-mentioned acid, which deprived the blue of colour; a particular and phlogiſticated earth which it could not diſſolve; do not theſe ſeem to announce, that this blue is not of the ſame nature with that which is precipitated from the ordinary phlogiſticated ley, in which M. Macquer found ſome iron, which could come from nothing but from the blood.

From all theſe facts I am of opinion we may conclude, that a great many experiments ſtill remain to be made upon Pruſſian blue, and that our knowledge of it is far from being complete. To what we have ſaid upon this ſubject I ſhall only add a few obſervations, with which an acquaintance is very requiſite.

1. Pruſſian blue, diſtilled with a naked fire, gives a very great quantity of inflammable gas; and at the ſame time ſome oil, concrete volatile alkali, and a little acid phlegm. This gas burns blue like that of marſhes: it has an empyreumatic odour: lime-water gives it the property of burning red and detonating with the air, becauſe it abſorbs the aërial acid which is united with it: it is found in the phlogiſticated alkali. M. de Laſſone looks upon the gas of Pruſſian blue as a particular inflammable gas.

2. Pruſſian blue, after this analyſis, puts on the form of a blackiſh powder, which the magnet attracts. Before it aſſumes this colour, it has an orange one, as M. de Morveau obſerved. This chemiſt was alſo of the opinion, that the Pruſſian blue, which the heat converted into an orange, might be of uſe in painting.

3. The volatile alkali, heated above Pruſſian blue, decompoſes it, ſeizing upon the colouring ſubſtance, and leaving the iron in the ſtate of ochre. M. Macquer, *anno* 1752, announced this fact. Meyer, who followed him, gave the name of *colouring liquor* to the volatile alkali ſaturated with the colouring part of the blue, and adviſed its uſe in analyſing mineral waters. I have obſerved, that when the volatile cauſtic alkali is diſtilled upon Pruſſian blue, the liquor which paſſes over has not the property of giving a blue colour to martial ſolutions; and conſequently the colouring principle is not ſo volatile as the alkali. When only a part of this ſalt has come over by diſtillation, the reſiduum is of an

olive-green: by dilution with diſtilled water and filtration, this liquor is charged with the colouring part, and gives a very lively Pruſſian with martial vitriol.

4. I diſcovered that lime-water, digeſted with Pruſſian blue, diſſolved the colouring matter by means of a little heat. The combination is very rapid. The lime-water becomes coloured, and the blue aſſumes the colour of ruſt. The lime-water, filtrated, is of a clear yellow colour: it does not turn the ſyrup of violets green: it has no longer an alkaline taſte, and the aërial acid does not occaſion any precipitation: it does not unite with the other acids: in a word, it is neutraliſed by the colouring matter of the blue; and by being poured into a ſolution of martial vitriol, it gives an elegant blue, requiring no acid in order to brighten it.

5. The cauſtic fixed alkali, in the cold, quickly deprives the blue of its colour. I have obſerved, that a very briſk heat takes place in theſe experiments; that the alkalis, in their ſtate of purity, attract the colouring matter from a much greater quantity of Pruſſian blue than when they are ſaturated with the chalky acid; and with the martial ſolutions afford a much greater quantity of blue than when in the ſtate of ſaturation with that acid.

6. I have found that magneſia likewiſe has the property of taking the colouring matter from the blue; but its power is much weaker than that of lime-water *.

7. Pruſſian blue, pounded, and projected upon nitre in fuſion, produces ſome ſparks, which denote that it contains ſomething combuſtible.

8. Pruſſian blue, prepared without alum, acquires the property of being attracted by the magnet by means of

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* I give here the general reſults only of ſeveral important facts which the decompoſition of the Pruſſian blue, by means of the alkaline ſubſtances, preſented to me: I reſerve a more complete deſcription of them for particular memoirs.

of a ſlight calcination; but that in commerce never acquires this property by the action of fire.

Martial vitriol very eaſily decompoſes nitre. This decompoſition is owing in part to the vitriolic acid, which, uniting with the alkali of the nitre, drives off the nitrous acid; but it is in a great meaſure occaſioned by the reaction of the iron upon the nitrous acid. If for this purpoſe we uſe martial vitriol moderately dried, a very great quantity of very red fuming nitrous acid is obtained; the reſiduum, waſhed, furniſhes vitriolated tartar and ſome fixed alkali; and a ſweet earth of vitriol remains upon the filtre: but if a vitriol ſtrongly calcined has been employed, we get a very ſmall product. This product ſeems to be formed of two liquors; one of which, being of a dull and almoſt black colour, ſwims above another one, which is red and weighty, as an oil would do above water: on this account M. Baumé conſidered this liquor as a kind of oil. A white ſaline maſs paſſes into the neck of the retort, which attracts humidity from the air, diſſolves in water with rapidity and heat, emitting a ſtrong odour of ſpirit of nitre and very thick vapours. This ſolution, ſaturated with fixed alkali, gives vitriolated tartar; hence the white maſs is only oil of vitriol, rendered concrete by a portion of nitrous gas. The weighty liquor of the balloon does not appear to differ in any reſpect from Glauber's ſpirit of nitre; but the light liquor which ſwims above it, being mixed with oil of vitriol, produces a briſk effervеſcence, and even a dangerous exploſion: almoſt all the nitrous acid is diſſipated, and the oil of vitriol remains, but in a concrete and cryſtalliſed form. M. Bucquet, who communicated this diſcovery to the academy, had at firſt obſerved that the concrete oil of vitriol obtained in this diſtillation emits red nitrous vapours when it diſſolves in water. He thought that this acid owed its ſolidity to the preſence of the nitrous gas; and in order to be convinced of this, he tried to mix the blackiſh brown nitrous acid, which ſwam above the red, with very concentrated oil of vitriol: but in the very moment of the mixture of theſe two ſubſtances, ſo rapid a commotion took place in the mixture, that the nitrous acid, which was poured upon the vitriolic, was driven to a great diſtance with conſiderable noiſe: the perſon who made the mixture was covered with it; a great number of red and inflamed pimples immediately roſe upon his face, which ſuppurated like the ſmall-pox. The oil of vitriol became concrete, and entirely ſimilar to that obtained in the diſtillation juſt now deſcribed. It appears that this acid may owe its concrete ſtate to gaſes of a different nature; and perhaps that which M. Hellot obtained from martial vitriol, diſtilled without any intermedium, is it rendered glacial by the preſence of ſulphureous gas. What remains after the diſtillation of nitre with martial vitriol calcined to redneſs, is only a kind of ſcoriæ of iron, from which we can obtain but very little vitriolated tartar by waſhing.

We do not know if the ſolution of martial vitriol might be precipitated by inflammable gas: it ſeems that in this experiment the iron aſſumed that which it loſt in its ſolution by the vitriolic acid; ſince, from M. Monnet's obſervation, the gas of liver of ſulphur, precipitated by an acid, gave the property of furniſhing cryſtals to a vitriolic mother-water.

Liver of ſulphur precipitates martial vitriol of a blackiſh colour. This precipitate is a kind of combination of iron with ſulphur.

The nitrous acid is rapidly decompoſed by iron, which diſengages from it a great quantity of nitrous gas, particularly if the acid made uſe of is concentrated, and if the iron is divided. In this caſe, the metal is almoſt entirely calcined by the air, which it takes from the nitrous acid. The ſolution is of a brown red; in a certain time it allows the martial ochre to be depoſited, becauſe it contains a vercy calcined iron. If, in this ſtate, more iron is put into it, the acid diſſolves it, as Stahl has ſhown, and the calx of iron which it held diſſolved is inſtantly precipitated. However, by employing a weak nitrous acid and iron in ſmall bits, a more permanent ſolution may be obtained, in which the metal is more adhering to the acid. This laſt combination is greeniſh, and ſometimes of a clear yellow. Both theſe ſolutions, when evaporated, grow turbid, and depoſite the martial ochre of a red brown. If it is ſtrongly evaporated, inſtead of affording cryſtals, it turns into a reddiſh yellow, which is only in part ſoluble in water, and of which the greateſt portion precipitates. By continuing to heat the martial nitre, many red vapours are diſengaged, the maſs dries, and gives a calx of a red like that of bricks. This maſs diſtilled in a retort, furniſhes a little fuming nitrous acid, much nitrous gas, and ſome aërial acid: no pure nor dephlogiſticated air can be obtained; which is undoubtedly owing to the calx of iron, which is very well calcined in this ſolution, not being reducible. The laſt gas which I obtained, goes to ſupport the conjecture which I have given about the preſence of the chalky acid in the acid of nitre. The calx which remains after the diſtillation of martial nitre, is of a lively red, and might furniſh a fine colour for painting. A ſolution of martial nitre, however copious, did not appear to me to be precipitated by the affuſion of water. The alkalis decompoſe it with phenomena, differing according to their nature. The cauſtic fixed alkali precipitates it in a clear brown; the mixture very ſoon changes to a blackiſh brown, and much deeper than the colour of the firſt ſolution. This phenomenon ariſes from this, that a portion of the precipitate is diſſolved in the alkali, though in very ſmall quantity. The mild fixed alkali throws down a yellowiſh calx, which very quickly becomes of a fine orange red. If the mixture is agitated whilſt the efferveſcence goes on, much more of the precipitate diſſolves than of that by the cauſtic alkali. M. Monnet has taken notice of this phenomenon, and attributes it to the gas which is produced. This ſolution of iron by the fixed alkali is called *alkaline martial tincture of Stahl.* It is of a very fine red. For its preparation, M. Baumé recommends taking a nitrous ſolution of iron, containing but a moderate portion of iron. On the contrary, Stahl adviſed a very ſaturated ſolution. M. Monnet obſerved, that a yellow ſolution gave a great deal of precipitate, almoſt none of which rediſſolves in the alkali, and which does not colour it as the martial tincture ought to be; whilſt a very red ſolution inſtantly makes one with the ſame alkali.

The alkaline martial tincture of Stahl loſes its colour in a certain time, and allows the calx of iron which it contains to be depoſited. It may be decompoſed by means of an acid. The acid of nitre throws down a calx of a red colour like that of bricks, which is ſoluble in the acids, and called *Stahl's crocus martis aperiens.* The pure or cauſtic volatile alkali precipitates the nitrous ſolution of iron of a deep green and almoſt blackiſh. Aërated ſal ammoniac rediſſolves the iron which it has ſeparated from the acid, and produces a ſtill more lively red than the tincture of Stahl. This ſolution of iron might be of great advantage in caſes where a powerful tonic and deobſtruent are both indicated.

The copious and red martial ſolution gave me always but very little true Pruſſian blue by means of the alkali ſaturated with the colouring matter of this compound. I had only a blackiſh precipitate, which is rediſſolved by the marine acid; the liquor had then a green colour.

M. Maret, ſecretary to the Academy of Dijon, has communicated to the Royal Society of Medicine a very ſpeedy proceſs for making martial æthiops: it conſiſts in precipitating the nitrous ſolution of iron by the cauſtic volatile alkali waſhing and drying the precipitate quickly. M. d'Arcet, appointed by this company to examine M. Maret's proceſs, did not obtain conſtantly the ſame reſult with this phyſician. In my Memoirs upon the Martial Precipitates, preſented to the Academy anno 1776-77, I have determined the caſes in which M. Maret's experiment ſucceeded, and in which it did not. For this purpoſe, 1. The ſolution of iron muſt be freſh made, and it muſt have been made in the cold very ſlowly with a weak acid, and the iron muſt be very minutely divided: 2. That the volatile alkali be recently prepared, very cauſtic, and, in particular, by repoſe deprived of the ſmall portion of calcareous earth and blackiſh combuſtible matters which uſually riſe from the ſal ammoniac and lime: 3. That the precipitate be inſtantly ſeparated from the liquor, and rapidly dried in cloſe veſſels. In ſpite of all theſe precautions, this precipitate is ſometimes not very black; it gets a light brown colour: its ſurface may be taken off in ſcales, the inferior ſurface of which is blackiſh; which proves that the contact of the air ſlightly ruſts the upper ſurface. I have obtained an æthiops more beautiful and more certain by precipitating the marine and acetous ſolution of iron by means of the cauſtic fixed and volatile alkalis, and by rapidly drying theſe precipitates after they were well waſhed in cloſe veſſels. But notwithſtanding all this, I think that theſe kinds of æthiops, however pure they are ſuppoſed, always retain a ſmall portion of their precipitants and firſt ſolvents, as M. Bayen has obſerved with regard to the precipitates of mercury; and that they ought not to be employed in medicine with as much confidence as thoſe which I ſpoke of before. M. d'Arcet, in his report to the Royal Society of Medicine concerning M. Maret's proceſs, has communicated another of M. Croharé's for making martial æthiops. This apothecary, celebrated for ſeveral well-executed chemical works, prepares this medicine by boiling water, acidulated with a little nitrous acid, upon iron-filings. The metal is inſtantly very much divided, and affords a great quantity of æthiops; but as it might be ſuſpected to retain a ſmall quantity of acid, would it not be ſurer to prefer

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M. Joſſe's proceſs, which is of very eaſy execution, and whoſe uſe can inſpire no ſuch apprehenſion?

The marine acid diſſolves iron with rapidity; the ſolution ſends off a great quantity of an inflammable gas, which ſeems to be produced in greater quantity than from the ſolution of this metal in vitriolic acid. It likewiſe has a ſmell ſomewhat different from that of the vitriolic inflammable gas. Does not this phenomenon ſeem to prove that one of the principles of the marine acid is a combuſtible body? M. Lavoiſier inclines to this laſt opinion. He thinks that the inflammable gas differs according to the acid employed; and that that which is diſengaged from the ſolution of iron in the marine acid is one of its principles. The marine ſolution of iron produces a great deal of heat: the heat continues till the acid be ſaturated: a portion of iron is precipitated in form of a true æthiops, as in all the other ſolutions.. After it is filtrated, it is of a green colour, inclining to yellow: it is much more ſtable than the two preceding. If it is put into a well-corked bottle, which is filled with it, only a very ſmall quantity precipitates. I have kept ſome of it theſe four years in this ſtate, which has ſuffered but a ſmall depoſition of a pale yellow: if, on the contrary, it is expoſed to the air, in ſome months almoſt all the iron which it contains is precipitated of a deeper colour than that of the preceding; and by keeping it in a tight bottle, but which is half empty, it depoſites more than the firſt, and leſs than the ſecond. This experiment, which I made with great accuracy, proves that the air has great ſhare in the decompoſition of all the metallic ſolutions. This phenomenon happens in all the ſolutions of iron, and it is a general obſervation with reſpect to thoſe of almoſt all the metals. Stahl announced, that the marine acid, in its combination with iron, aſſumed the characters of ſpirit of nitre: but this fact has not been obſerved by any chemiſt: it ſeems that Stahl referred only to the yellow colour of this ſolution, and to the ſmell which it emitted; a ſmell indeed a little different from that of the pure marine acid. The marine martial ſolution evaporated does not cryſtalliſe regularly. M. Monnet obſerved, that if it is left to cool when it is in a ſyrupy conſiſtence, it forms a kind of maſs, in which cryſtals are ſeen flattened and in form of needles, which powerfully attract humidity. This maſs fuſes with a very gentle heat, and ſeems to merit the name of butter of iron: by a ſtronger heat it is decompoſed, but not ſo eaſily as martial nitre, and it aſſumes a ruſty colour when it is dry. The marine acid ſeparates from it, and may be obtained by diſtillation; which, according to M. Brandt's remark, carries along with it a little calx of iron. M. le Duc d'Ayen, in one of the four excellent memoirs which he has given to the Academy concerning the combinations of the acids with the metals, has at great length examined what paſſes in this decompoſition of the martial marine ſalt in a retort. This operation afforded him very ſingular products: at firſt an acidulated phlegm came over with a gentle heat; the marine acid is then concentrated, and its gas, much more volatile than the water, was in part fixed by the iron. With a ſtronger fire, a little of the acid was raiſed along with ſome iron; and ſome cryſtals, not deliqueſcent, are formed in the balloon. At the ſame time cryſtals are ſublimed along the ſides of the retort, which are tranſparent, very light, and in form of razor-blades, which decompoſed the light like the beſt priſms, and exhibited very beautiful ſhades of red, yellow, green, and blue. At the bottom of the retort a ſtyptic deliqueſcent ſalt remained of a brilliant colour and leafy form, which exactly reſembled the ſpecies of mica in large laminæ, which are improperly called *talc* or *Muſcovy glaſs*. This laſt ſalt, when expoſed to a violent heat in a retort of free-ſtone, is decompoſed, and furniſhes a ſublimation ſtill more aſtoniſhing than the former products. It was an opaque matter truly metallic, which, when examined by the microſcope, preſented regular cryſtals or edges of hexagonal priſms, which M. le Duc d'Ayen compares to the ornaments in the cielings of rooms. Theſe cryſtals were as brilliant as the moſt poliſhed ſteel, and the magnet attracted them very ſtrongly: this, we ſee, was iron reduced and volatiliſed *.

From theſe accounts, it is evident how fully ſtored chemiſtry is with ſingular phenomena, and how great diſcoveries this beautiful ſcience promiſes to thoſe who would incline to make as accurate and complete experiments as M. le Duc d'Ayen has deſcribed in his reſearches.

Let us not forget to obſerve, that this reduction of the iron favours the pneumatic doctrine; and perhaps ſimilar products might be obtained from many other metallic ſolutions when treated in the ſame way.

The ſolution of martial marine ſalt is decompoſed by lime-water and the alkalis, like all the martial ſolutions: but theſe precipitates are leſs altered, and may be very eaſily reduced, particularly thoſe which are reduced by the cauſtic alkalis. I have already obſerved that this combination gave the pureſt æthiops by precipitation. Liver of ſulphur, hepatic gas, and inflammable gas, decompoſe it as they do the other two.

Water, charged with aërial acid, eaſily diſſolves iron. For this purpoſe, it is ſufficient to put ſome filings into this acid ſpirit, and leave the mixture in digeſtion for ſome hours. This liquor, when filtrated, has a ſharp and a little ſtyptic taſte. Meſſ. Lane and Rouelle acknowledged this property in the chalky acid. M. Bergman, who calls this combination *ferrum aëratum*, ſays, that when expoſed to the air, it becomes covered with

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* I have in my cabinet a black ore of iron, which preſents very ſmall brilliant laminæ half a line in breadth, whoſe form greatly approaches to the cryſtals obtained by M. le Duc d'Ayen. They are ſmall very thin ſcales of a very ſhining iron gray, laid horizontally, which croſs one another in all directions, and which are ſcattered on a reddiſh opaque quartz, or a kind of coarſe jaſper. This pretty ſpecimen came from Lorraine.

a pellicle of the colours of the rainbow, which the pure alkalis decompoſe, but when combined with fixed air have no ſuch effect. This ſolution turns the ſyrup of violets green, and gives Pruſſian blue with the phlogiſticated alkali; ſome martial ochre precipitates, when it is left expoſed to the air, or when it is evaporated. I think it ſhould be called *creta martialis.* Iron has a a great tendency to unite with the chalky acid. Nature preſents it to us very frequently in this ſtate: bog iron ores, ſparry iron, appear to be entirely formed of this combination. The martial mineral waters contain the iron frequently in the ſtate of creta martialis. This ſalt, ſeparated from water, and dry, has but little tendency to diſſolve in this fluid: but it diſſolves in great quantity in the ſpirit of acid of chalk; from which it precipitates in proportion to the volatiliſation of the acid.

Iron makes nitre detonate: by projecting into a very red crucible a mixture of equal parts of filings of ſteel and very dry nitre, in a little time a very rapid motion commences; many very brilliant ſparks are thrown out of the crucible. When the detonation is finiſhed, the crucible contains a reddiſh calx of iron; a ſmall portion of which is combined with the alkali: by waſhing, the water diſſolves the alkali, and the martial calx remains upon the filter. It is called *crocus martis of Zwelfer.* It is of a reddiſh yellow, not very ſoluble in the acids. The alkali which is ſeparated by the waſhing is cauſtic, according to the moſt of the chemiſts, who think that moſt of the metallic calces act like pure lime upon this ſalt charged with aërial acid *.

Iron eaſily decompoſes ſal ammoniac. Two gros of filings of ſteel, triturated with a gros of ſal ammoniac, expel all the alkaline gas. M. Bucquet, who diſtilled this mixture in a pneumato-chemical apparatus with mercury, obtained fifty-four cubic inches of an aëriform fluid, the one half of which was alkaline gas, and the other inflammable gas. Four ounces of the ſame filings, and two ounces of ſal ammoniac, diſtilled in a retort with an ordinary recipient, gave about two gros of alkaline ſpirit charged with a little iron, which it very ſoon allows to depoſite in the ſtate of ochre. The reſiduum of theſe operations is a martial marine ſalt. The decompoſition of ſal ammoniac by iron is founded upon this, that this metal unites very well with the marine acid; which is proved by the diſengagement of the inflammable gas which is obſerved in this experiment. In pharmacy, a medicine is prepared with ſal ammoniac and iron, called *flores martiales ſalis ammoniaci*, or *ens martis*. A pound of ſal ammoniac in powder, and one ounce of iron-filings, are mixed together: this mixture is expoſed in an earthen veſſel covered with another of ſimilar materials to a fire capable of reddening the inferior part of this apparatus. In five or ſix hours a yellow matter is ſublimed, which is to be kept in a vial. Theſe are the flores martiales. This ſubſtance is formed in a great meaſure of ſal ammoniac ſublimed with a little calx of iron. As this metal very eaſily decompoſes ſal ammoniac, we muſt uſe but a ſmall quantity, in order that the greateſt part of the ſal ammoniac may be ſublimed without alteration. The portion of martial calx, which is volatiliſed by means of the marine acid and the volatile alkali, gives a colour to the ſal ammoniac.

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* It muſt be obſerved, that ſince the theory of Black upon cauſticity, the neceſſary experiments have not been made to determine this parity of action between lime and the metallic calces. Nothing complete can be ſaid upon this point, till experience evince the truth of the fact.

The calx of iron decompoſes this ſalt better than the metal itſelf does, diſengaging the volatile alkali even without heat. What is obtained by diſtillation is very fluid and ſufficiently cauſtic. I have got volatile alkali which effervefced with acids, by diſtilling ſal ammoniac with half its weight of crocus martis aperiens. In this experiment the aërial acid diſengaged from the iron unites with the volatile alkali, which is thus rendered efferveſcent.

Iron is acted upon by inflammable gas: but this alteration, which is very ſenſible from the colour, has not been examined anent the other properties of this metal.

Sulphur rapidly combines with iron. A mixture of filings of iron and of ſulphur in powder, moiſtened with a ſmall quantity of water, grows hot in a few hours: then it ſwells, agglutinates, abſorbs water, ſplits with a noiſe or evident crackling, and emits many aqueous vapours, accompanied with a very evident hepatic odour, ſomewhat ſimilar to that of inflammable gas. If the mixture is made of a great ſize, it inflames in twenty-four or thirty hours, and as ſoon as the watery vapours have ceaſed. Towards the mutual action of theſe ſubſtances, the heat augments with great rapidity, and the inflammation very ſoon takes place. The ſmell is then much more exalted, and ſeems to be owing to the inflammable gas produced by the reaction of the ſulphur and iron. This ſmell is mixed with that of liver of ſulphur and that of pure inflammable gas: and it is undoubtedly this inflammable gas which is diſengaged in great quantity, that cauſes the inflammation obſerved in this experiment, ſince the flame is much brighter than that of ſulphur. It is driven a foot upwards, according to M. Baumé, who obſerved this phenomenon from a hundred pounds of filings and as much ſulphur; it laſted only two or three minutes. The mixture remained inflamed or red for forty hours. M. Baumé explains this phenomenon by the diſengagement of the phlogiſton into free fire. Lemery the father called this an artificial volcano; and he imagined, that the fires which are kindled in the interior parts of our globe, and which, raiſing the ſurface of it, produce earthquakes and volcanos, were owing to a combination ſimilar to that of the pyrites heaped together and moiſtened. Theſe terrible effects, as the ſame chemiſt ſays, may be imitated, by burying in the earth a mixture of ſulphur in powder and iron filings reduced into a paſte with water, and covering it up with earth ſtrongly preſſed together. This experiment did not ſucceed with M. Bucquet, who repeated it with great exactneſs: but from Dr Prieſtley's experiments we may conceive the reaſon. This philoſopher has obſerved, that the mixture of iron and ſulphur moiſtened, abſorbed a certain quaintity of air, which is undoubtedly neceſſary to its inflammation. This laſt fact agrees very well with M. Lavoiſier's theory. Accordingly it ſeems, that the ſulphur very much divided by the reaction of the moiſtened iron, attracts a portion of the pure air of the atmoſphere, that it may change into vitriolic acid; then the iron is diſſolved, and produces inflammable gas, which kindles by the heat occaſioned in the mixture. On this account a great quantity of martial vitriol can be extracted from the mixture. There is a great analogy between this combination of the iron with the ſulphur by the humid way and the efloreſcence of the pyrites.

By fuſion ſulphur very eaſily combines with iron, and compoſes a pyritous matter diſpoſed in needles. As the ſulphur in this caſe greatly increaſes the fuſibility of the iron, this metal may be quickly fuſed by means of this combuſtible body. For this purpoſe we muſt paſs a ſmall bar of this metal, heated to whiteneſs, into a roll of ſulphur, and receive the fuſed matter in water. In the water we find black brittle globules ſimilar to the pyrites, and formed like thoſe of ſmall, very elongated, and concentric pyramids.

Arſenic combined with iron gives a coarſe, brittle, and very little known alloy: with cobalt it conſtitutes a mixed metal in ſmall compact grains, hard, and very difficult to break. It is preſumed not to unite with biſmuth.

Combined with antimony, it forms a hard alloy in ſmall facets, which the hammer but ſlightly flattens.

Iron has more affinity with the ſulphur than with the regulus; conſequently it has the power of decompoſing the antimony. Five ounces of Marechal nails are made red-hot in a crucible, and a pound of powdered antimony thrown in: a ſtrong quick heat is applied in order to fuſe the mixture: when it is well fuſed, an ounce of powdered nitre is projected, in order to facilitate by a proper fuſion the ſeparation of the ſcoriæ from the regulus: the materials are left to cool, and a regulus of antimony is found which does not contain any iron. If one part of iron to two of antimony be uſed, there will be a martial regulus. The ſcoriæ which are found above this laſt regulus, prepared with nitre and tartar, have a yellowiſh colour ſimilar to that of amber: for that reaſon Stahl has called them *ſcoriæ ſuccinatæ.* He preſcribes reducing them into powder, and boiling them in water. This fluid carries along with it the moſt divided part; it is then decanted, filtrated, and the powder remaining upon the filtre detonated thrice with nitre. It is waſhed and dried: and this is Stahl's crocus martis aperiens antimoniatus.

It is ſtill uncertain if zinc can unite with iron. M. Malouin, in his memoir upon Zinc, (Academy 1742), has ſhown that this ſemimetal may be applied, like tin, to the ſurface of iron, and defend it from the contact of the air; which is an indication that theſe two metals are ſuſceptible of combination.

Nickel appears to be capable of a very intimate combination with iron; theſe two metallic ſubſtances, according to M. Arvidſon, never admitting of an entire ſeparation.

Mercury in its metallic ſtate forms no union with iron. Their immediate combination has been in vain attempted; but they unite in the form of a calx. M. Navier has obſerved, that a ſnowy white precipitate was obtained from the admixture of a ſolution of iron and of mercury by the vitriolic acid; the mixture evaporated forms flat very light cryſtals reſembling ſedative ſalt. M. Navier has aſcertained that theſe cryſtals are combinations of iron and mercury.

Lead contracts no union with iron.

It is not known if iron and tin can unite by fuſion. The covering the ſurface of iron with a coat of tin, or the preparation of white iron, ſeems to ſhow that this combination takes place, as we are going to ſee. To tin the iron, the ſurface requires to be very convenient and brilliant; for which purpoſe it is ſubjected to the action of an acid or of a file, or of ſal ammoniac; then it is plunged vertically into a veſſel full of fuſed tin: it is turned up to increaſe the thickneſs of the coat; and when it is ſufficiently tinned, it is taken out and rubbed with ſaw-duſt or bran, to carry off the greaſe or pitch with which the fuſed tin was covered, and which had adhered to the ſurface of the tin-iron. If the iron to be tinned is reduced into ſmall plates, the tin will not only adhere to the ſurface, but will penetrate it, and combine with all its parts; and upon cutting it, the ſame white colour will be obſerved in its middle as at its ſurface; which ſhows that white iron, well prepared, is a true chemical combination: beſides, it is more malleable than iron; and of it veſſels are made of a form which this metal in its pure ſtate could not be made to aſſume.

The uſe of iron is ſo extenſive and ſo well known, that it were uſeleſs to inſiſt upon it. It is ſufficient only to know, that no art can diſpenſe with it; and, as M. Macquer expreſſes it, it is the ſoul of all the arts. The different modifications it can aſſume make it a ſubſtance very adequate for the multiplicity of uſes to which it is deſtined. The font ſerves to fuſe utenſils which are more or leſs ſolid, or have more or leſs reſiſtance, as neceſſity requires. The hardneſs and tenacity of forged iron very properly ſuit the various purpoſes to which it is applied. The ſame may be ſaid of the different ſorts of ſteel: the fineneſs of the grain and the temper conſtitute many kinds of it; all of which are made uſe of in the different arts to which they are adapted. The calces of iron ſerve to give a red or brown colour to the porcelains, the earthen wares, the enamels, and other ſubſtances. They are employed alſo in the preparation of the artificial precious ſtones, and combined with oil in painting.

In medicine iron is an important remedy, productive often of the moſt ſalutary effects. It is the only metal which contains nothing hurtful, and whoſe effects need not be dreaded. It has even ſuch an analogy, as we have already ſeen, with the organic matters, that it ſeems to make a part of them, and frequently to owe its production to the animal œconomy or to vegetation. The effects of iron upon the animal œconomy are ſufficiently numerous. It ſtimulates the fibres of the membranous viſcera, and ſeems to act in a ſpecial manner upon thoſe of the muſcles, whoſe tone it augments. It ſtrengthens the nerves, and gives the weakened machine a remarkable energy and vigour. It excites ſeveral ſecretions, particularly thoſe of the urine and ſanguine evacuations. It provokes natural hemorrhagies, as the menſtrual and hemorrhoidal fluxes. It increaſes and multiplies the contractions of the heart, and conſequently the force and quickneſs of the pulſe. It acts upon the fluids in no leſs degree. It eaſily paſſes into the circulation, and combines with the blood, to which it gives denſity, conſiſtence, colour, and a greater concreſcibility; at the ſame time it communicates to it ſuch an activity, as eaſily to paſs into the moſt minute veſſels, ſtimulating the ſides of the canals which contain it, ſupporting the energy and life. The beautiful experiments of M. Menghini, publiſhed in the Memoirs of the Inſtitutes of Boulogne, have proved, that the blood of perſons who have made uſe of iron is more coloured, and contains a greater quantity of iron, than it contains naturally. M. Lorry, who in the practice of medicine has cultivated this nicety of obſervation, and the pretty remarks which characteriſe the knowing phyſician and philoſopher, obſerved, that the urine of a patient to whom he adminiſtered iron in a very divided ſtate, was manifeſtly coloured with the gall-nut. This metal, then, is a tonic, corroborant, ſtomachic, diuretic, alterant, and an inciſive remedy, whoſe action comprehends the properties of a great number of medicines. Like aſtringents, it braces the fibres, and increaſes their oſcillation; and is preferable to other remedies which enjoy the ſame virtue, on account of the greater certainty and durability in its effects; becauſe it combines with the organs themſelves by the intermedium of the fluids, which ſerve for their nutrition. On theſe accounts, it is proper in all the caſes where the fibres of the viſcera, of the muſcles, and even of the nerves, have their action weakened; in the weakneſs of the ſtomach and inactivity of the inteſtines, and in the diſeaſes ariſing from theſe cauſes; and, laſtly, in all caſes where the fluids have not the proper conſiſtence and concreſcibility, but are too watery, as in pale habits, and in thoſe diſpoſed to dropſy, &c. It is employed under many different forms; as the porphyriſed limatura martis, martial æthiops, crocus martis aperiens and aſtringens, tinctura martialis alkalina Stahlii, flores martiales. To theſe medicines might be added, perhaps, the iron precipitated from the acids and rediſſolved by the volatile alkali, ſal martialis ſedativus, and the Pruſſian blue recommended by the academy of Dijon. Externally, martial vitriol is uſed as a ſtyptic in hemorrhagies and the like.

Iron, poſſeſſing the power of magnetiſm, or the artificial magnet, produces alſo ſingular effects upon the animal œconomy. Applied to the ſkin, it relieves pains, allays convulſions, excites redneſs, ſweat, and frequently alſo an eruption of ſmall pimples: it ſeems alſo to impede the acceſſion of epileptic fits. Left in water for a dozen of hours, it is ſaid to communicate to it a purgative property. Although all theſe facts require to be confirmed by many experiments, it cannot be doubted that the magnet has a very ſenſible virtue. M. Thouret phyſician of the Faculty of Paris, and of the Royal Society of Medicine, has communicated, in the firſt volume of this laſt company's hiſtory, a beautiful obſervation relative to this ſubject. A patient at Rouen complained of a fixed pain in the different branches of the ſeventh pair of nerves diſperſed upon the cheek, by applying a magnet to the different parts of this region, the ſkin ſeemed to make reſiſtance to the magnet. There is no queſtion that new obſervations will confirm theſe diſcoveries, and elucidate the practice of phyſic; which ſome perſons have been inclined to render more intricate by making it appear myſterious *.

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* The iron of Great Britain is made from three different kinds of minerals. From iron-ore, commonly called *Lancaſhire ore*, from the name of the county where it is found in greateſt abundance. This ore is very heavy, of a fibrous or lamellated texture: the colour is dark purple, approaching to a ſhinning black, and when reduced to powder it becomes of a deep red: it lies in veins like the ores of moſt other metals, from which it is dug in a ſimilar manner. The bog-ore reſembles a deep yellow ochry clay, and ſeems to be the depoſition of ſome ferruginous rivulet, whoſe courſe had formerly been over the ſurface of a flat marſhy plain. It lies in beds of an irregular thickneſs, commonly from twelve to twenty inches, and is very various in its breadth from ſide to ſide; ſo that it never forms a uniform extended bed of any great dimenſion. Miners, who are accuſtomed to ſearch for bog-ore, know where to dig, by examining the nature of the plants which grow upon the ſurface, as they always indicate the quality of the ſoil which is beneath them. The iron-ſtone has no regular appearance, and does not in the leaſt reſemble a metal externally. It lies in beds of great extent like other ſtony matters, and is commonly ſtratified with ſeams of pit-coal, forming alternate layers; though theſe are not always rich enough to repay the expence of working. Such are the chief differences of the three principal minerals from which iron is obtained; although there is an infinite variety in the quality and appearance of the iron-ore and iron-ſtone.

The ores of iron are in general roaſted before they are put into the furnace for fuſion. This operation is not always performed in order to free the minerals from ſulphureous and other volatile matters, as many of the ores contain no ſuch matters. But then the proceſs of roaſting calcines the adhering matrix, makes the ſiliceous earth crack, and renders the whole maſs ſo friable, that it may be eaſily broke into fragments of a convenient ſize for melting. After the mineral is duly prepared, it is next ſubjected to the moſt intenſe heat which the force of fuel can raiſe in a furnace; and if the quality of the mineral requires an addition, a certain portion of limeſtone is added to promote and facilitate the fuſion of the metal. The furnaces which are erected for melting iron, conſiſt of a large capacious cavity, from ſixteen to twenty-five feet high, and from ten to fourteen wide: the moſt approved ſhape nearly reſembles that of a hen's egg, with the largeſt end undermoſt; below which there is a ſquare cavity to contain the melted metal, and at top a very ſhort vent about twenty inches in diameter. The inner wall is built of fire-ſtone, which indures a ſtrong heat with little riſk of melting, and has all the joints cemented with mortar compoſed of ſand and clay. This is ſurrounded with more building, which deviates more and more from a circular form, and the whole is incompaſſed with a ſquare building, which is about twenty feet at the baſe, and gradually converges to the top. This outer wall conſiſts of very large ſtones, and is ſometimes bound round with large beams of wood to give additional ſtrength, and to fortify the whole building. The foundation of ſo large a maſs muſt be quite ſolid. But under the hearth a void ſpace is left, by means of an arch, to prevent any watery moiſture from cooling the bottom of the melted metal. The hearth is compoſed of a large flat ſtone; and upon every ſide of it a ſtone is ſet on edge about eighteen inches deep, which forms the ſquare cavity made at the bottom of the furnace to collect the metal. One of the ſtones is ſomewhat ſmaller than the reſt, which leaves an opening above it in order to give vent to the ſcoriæ after the metal has riſen to a certain height. A little above the edge of this cavity, ſoon after the body of the furnace begins to ſwell, a hole is made in the wall to permit the noſel of the bellows to enter, and a proper vacuity is left in the ſame ſide of the building to lodge the body of the bellows. It is a matter of ſome nicety to proportion all the parts to each other ſo that the furnace may work well: and the principle upon which the perfection of a furnace depends is ſtill ſo little underſtood, that the conſtruction of iron furnaces is varied in different countries, more from caprice than from judgment and experience.

After the whole ſtructure is completed, the great cavity is filled with charcoal, which is kindled at the top, to heat the body of the furnace gradually. When the charcoal has burnt down a certain length, the founder begins to charge the furnace with proper materials for working. This charge conſiſts of charcoal, limeſtone, and the irony mineral mixed together in a juſt quantity. The founder muſt be extremely attentive that none of the materials exceed the proportion which it ſhould bear to the reſt. If the quantity of charcoal be too large, the exceſs burns in pure loſs, the iron is too much ſcorified, and does not poſſeſs the ſame excellent quality it would have done, had the proportions been more juſt. If the charcoal be added in too ſmall quantity, then the iron is not ſufficiently purged from the heterogeneous matters which vitiate the quality, the matrix is ſtill left crude, full of large brilliant laminæ and ſulphureous particles. Beſides, when the furnace has been once overcharged with the mineral, it never can afterwards be brought to conſume ſo large a quantity as it would otherwiſe have done. For this reaſon the founder muſt attend the furnace with aſſiduity and care during the firſt days of working, in order to learn the trim; and he ſhould all the while be attentive to augment the proportion of the mineral gradually, ſo that the furnace may never be overcharged by the injudicious addition of too large a quantity at once.

The moſt intenſe heat is excited oppoſite to the blaſt of the bellows; and as the mineral deſcends gradually from the top of the furnace, it is prepared for fuſion before it reaches the blaſt. The chief part of the operation, the converſion of the ore into metal, goes on at this point: and as ſome eſtimate of the perfection of the proceſs may be formed from inſpection, the founder often looks through the hole where the bellows enters, to obſerve what paſſes within. He there perceives the metal falling down in drops like rain, which collect in the baſon at the bottom of the furnace. The pure metal ſinks below from its ſuperior gravity, while the ſlag or ſcoriæ, which conſiſt of the earthy matters, converted almoſt into a vitreous maſs by the force of the heat, float atop of it. At certain intervals, the metal collected in the baſon will become agitated with great inteſtine commotions, boil and bubble up, and emit vivid ſparks, which ſeem to deflagrate in the air. Thoſe fits of ebullition will continue for half an hour at a time, and return at ſtated periods with wonderful regularity. They are ſuppoſed to purify the metal, though the cauſe of the phenomenon is not well underſtood. Sometimes the furnace will take a ſcouring, and melt away, till a large excavation is formed on the ſide of it, without any perſon being able to aſſign a reaſon why it ſhould begin, or why it ſhould ceaſe. The excavation moſt commonly occurs in the loweſt part of the wall oppoſite to the blaſt, or on the higher part of the wall on the ſame ſide with the bellows.

An intelligent workman can judge, with great correctneſs, of the perfection of his *font* (the term uſed for the quantity of metal run from the furnace at once), from obſerving the appearance of the flame which iſſues from the top of the furnace, and from inſpecting the colour and conſiſtence of the ſcoriæ which flow from the ſurface of the metal. When the flame riſes to a great height above the furnace with clouds of thick ſmoke, attended with a number of ſparks ſhooting to a diſtance in the air, we may expect an ebullition on the hearth. When the anterior wall is covered with a brown and ſmoaky colour, we may be aſſured that the minerals are not completely fuſed, and that the pure, heavy, metallic parts are not thoroughly ſeparated from the light impure ſcoriæ: but, on the contrary, a green tint, verging to a white, denotes an excellent ſtate of the fuſion. With regard to the appearance of the ſcoriæ, if they ſeem full of brilliant particles or ſcales, if they run white from the hearth, eſpecially towards their extremities, or if the ſcoriæ be very light and limpid as water, with a ſmall degree of tenacity, and if they harden immediately upon expoſure to air; all thoſe circumſtances mark a heat too much concentrated, which muſt be tempered by the addition of more mineral. If the ſcoriæ are opaque and black, there has been a deficiency of charcoal; but if they be black, reſembling the colour of iron, and at the ſame time light, we may conclude that a juſt proportion of charcoal and mineral has been employed. Yet, after all, the moſt expert workmen agree, that the nature and quality of the metal is affected by the occurrence of a thouſand unknown circumſtances, which we do not thoroughly underſtand, and which it is by no means eaſy to inveſtigate.

A good-going furnace will often yield from three to four tons of iron in the courſe of twenty-four hours. The metal is let out commonly at three intervals, by driving a hole with a punch contiguous to the ſmall ſtone of the baſon; and when the whole has run out, the hole is well ſhut with clay until there is occaſion to open it again. This operation is called *tapping the furnace.* The metal is run into moulds of whatever ſhape and ſize the workman wiſhes. The bellows is ſtopped during the flow of the metal, and opened immediately after, as the furnace is continually ſupplied with a freſh charge when any part of the former is exhauſted. In this manner it is kept working perpetually, until part of it fall into decay by uſe.

Iron that flows from the furnace is called *caſt iron*, *pig iron*, or *yetlin.* It is very hard and brittle, does not admit of extenſion under a hammer, and commonly receives but little impreſſion from the teeth of a file. Thoſe properties are directly contrary to the properties which malleable iron poſſeſſes: for malleable iron is neither brittle nor hard, admits of great extenſion under a hammer, and may be ſhaped into any form by means of a file; but is altogether infuſible in the greateſt heat which it is in the power of fuel to excite, however long it be expoſed to its action.

The difficulty of making good caſt iron is ſo very great, that the moſt ſagacious workman cannot always promiſe to run every font of the ſame quality: there is even a difference in the quality of the different parts of one font; and this is ſometimes ſo remarkable, that one half of a kettle proves hard, while the other half proves ſoft, although the whole metal be run out at once from the furnace. Variations, ſo great as this, are attended with great practical inconveniences; ſo that it becomes an object of conſequence to correct the fault completely.

In order to aſcertain how long iron retained its ſoftneſs, M. Reaumur kept ſome ſoft iron in fuſion, taking out a ſmall portion at different intervals to try the quality. What was taken out firſt, proved ſoft when cold; after a quarter of an hour it ſtill yielded to the file, but with more difficulty; after remaining fuſed another quarter of an hour, it proved hard, and did not yield to the file at all. M. Reaumur found in the trials which he had made for this purpoſe, that caſt iron, remelted in a crucible with animal bones and a ſmall quantity of charcoal-duſt, was rendered ſoft and uniform in its quality. He found, at the ſame time, when kept in fuſion without addition, the contrary effect took place, and that ſoft iron became even brittle by this proceſs. In the courſe of examining the beſt method of ſoftening caſt iron, M. Reaumur at laſt diſcovered, that the mere application of heat was alone ſufficient, provided the requiſite degree was employed. This was ſomewhat nice to regulate; for if the heat did not exceed a cherry red, no length of expoſure was of the ſmalleſt ſervice: The operation began as the heat increaſed, and ſucceeded beſt when it approached to the fuſing point; for thoſe plates were moſt completely ſoftened whoſe edges had begun to melt. In theſe experiments there was an opportunity to obſerve the progreſſion of the change, which began at the ſurface, and proceeded gradually towards the centre. The outſide was ſometimes fairly converted into ſoft malleable iron, while the internal parts retained their original texture. The diſtinction is ſufficiently marked. Malleable iron is of a lamellated, caſt iron of a granulated, texture. The good or bad quality of the caſt iron is determined from the colour, ſize, and diſpoſition of the grains. What is in general moſt eſteemed has the grains fine, diſtinct, apart from one another, and approaches nearly to the appearance of ſteel tempered with a gentle heat: and with regard to colour, the browneſt are the moſt eaſily kept ſoft. That which has a black colour with a fine diſtinct grain is the moſt malleable of all. Of two different fonts, one ſhall be of a lighter grey, and better grained; the other ſhall be of a deeper black, with larger and leſs diſtinct grains. In this caſe we prefer that which has the moſt perfect granulation: for in common we lay much more ſtreſs upon the texture of the grain than upon the tint of colour. After all, we muſt confeſs, that thoſe marks often prove fallacious, this metal is ſo various in its nature.

Caſt iron is extremely valuable from the extent of its uſe to the purpoſes of life. By the improvement of the manufacture, it is formed into a great variety of utenſils. It is employed for ſmall or large work, from the leaſt-ſized tacket up to the largeſt piece of ordinance weighing many tons.

Caſt iron, as was before obſerved, is not malleable. In order to make it ſo, the Swedes, who are reputed to make the beſt bar-iron, purify the font by repeated fuſions. The firſt part of the proceſs is to place the iron upon a mixture of charcoal-duſt, and the ſcoriæ of former meltings, before the blaſt of a bellows driven by water.

The blaſt plays into a cavity about eighteen inches deep, and is directed ſo as to ſtrike the angle where the bottom and oppoſite ſide join. The cavity is filled till within one third of the top with the mixture of charcoal-duſt and ſcoriæ, upon which the maſs of iron is placed obliquely, in order that it may be parallel to the direction of the blaſt, which plays chiefly upon the under ſide; and the metal ſtands about ſix inches diſtant from the nozel of the bellows. The whole is then covered with charcoal, which is kindled below, and the bellows is ſet a-working. The ſcoriæ promote the fuſion of the iron, which melts at the under ſide; and as it runs down the workmen puſh it nearer the bellows, that the melting ſurface may be all the while retained at the ſame diſtance from the blaſt. When all the metal is melted, it begins to ſwell and bubble at the ſurface, and will ſometimes riſe above the edge of the cavity. The tenuity of the fuſion muſt be ſuch as will permit the foreign matters to ſeparate from the metal. This kind of boiling is continued about half an hour, prolonged at the diſcretion of the workman, if he judge longer time requiſite from the quality of the metal. Once the metal is ſo cool as to fix, it is ſubjected to the ſame operation, repeated almoſt in a ſimilar manner. In this ſecond operation the workman is attentive to expoſe the upper ſurface of the metal firſt to the influence of the fire, and takes care to turn the iron, ſo that the whole maſs may melt uniformly. After the maſs melts, it throws off ignited charcoal-duſt and ſcoriæ, forming whirls of fire all over the forge. This is ſuppoſed to be a true purification of the iron, which laſts about ſeven minutes, and the whole proceſs conſumes about two hours. The next ſtep is to beat the iron with a forge hammer, when a great deal of ſcoriæ and other impurities are expelled from the metal. About 350 lbs are commonly prepared at a time, and about 24 tons of charcoal are allowed to the workmen for every 400 lbs of malleable iron. By this proceſs caſt iron is rendered fit for the uſe of the blackſmith; and if the ſucceſs has been complete, the iron is alike ductile when it is hot and when it is cold. But there are two imperfections which frequently degrade the quality of the metal. One is a great degree of fragility when hot, though it is ſufficiently ductile and tenacious when cold. The other is the converſe of this, ductile and tenacious when hot, fragile when cold. Iron with thoſe faults is called by the workmen *red ſhort* and *cold ſhort iron*; and that which is cold ſhort is accounted the worſt and moſt troubleſome fault. They ſeem ſo far to depend upon the nature of the ore, that a founder cannot always correct them by the moſt dextrous and judicious management. Faultleſs iron has been long ſought after; and of late a method has been diſcovered of converting yetlin into malleable iron with great eaſe and certainty. The improvement conſiſts in running caſt-iron into an air-furnace, where it is kept about the conſiſtence of wax by a proper regulation of heat. The furnace is open at both ends, and the flame of the fire blows over the ſurface of the metal. The ſide-walls are perforated with round holes, through which the workmen keep pockering the metal with iron rods. During this operation the iron is continually emitting a blue vapour; the nature of which has not yet been examined with care. There is no violent ebullition, nor any other remarkable appearance takes place, while the converſion is going on, which is thoroughly completed in the ſpace of two hours with a maſs of iron weighing 600 lb. The malleable iron obtained at the end of the proceſs has all the qualities of good metal, and can be made from pigs of all kinds; which is not the caſe in the other ways of working. Upon what principles the change happens, is not thoroughly underſtood; though it ſeems ſufficiently evident that the effect of heat is to expel ſome volatile matter from the caſt-iron, which flies off under the form of blue vapours.

As the erection and ſupport of a blaſt to fuſe iron is attended with conſiderable expence, ſome improvers have tried to melt down the iron ſtone by the force of ſuch a current of air as could be raiſed by the conſtruction of the furnace. An attempt was lately made near Edinburgh, with great hopes of ſucceſs; but, after the fire had laſted for a week, no fuſible iron was procured. There was a ſmall quantity of malleable iron at the bottom, and a large quantity of metallic matter remained in the ſlag. This experiment ſhows, that it is more eaſy to make malleable iron than caſt iron. It is probable, that, ſome time back, no other kind of iron could be made; and this conjecture is confirmed by the richneſs of the ſlags which are found near old iron-works: theſe are now wrought over again in many places with ſufficient profit. At the furnaces in Navarre, the iron is not brought into fuſion, but reduced from the ore in a kind of furnace, open at top, and carried from that directly to the forge-hammer, without the intervention of any intermediate proceſs.

Two ſeparate pieces of malleable iron unite perfectly into one, when made red-hot in the fire and hammered on the anvil. This operation is called *welding*, and the heat requiſite is called a *welding heat*. It is cuſtomary to throw ſome ſand into the fire along with the iron, which vitrefies the ſcoriæ, and keeps them ſo fluid, that they are ſqueezed out with the blows of the hammer; and thus the clean ſurfaces of the heated iron are permitted to approach each other. In this way anchors for large veſſels are made, up to the weight of two ton. Soft iron is alſo uſed for the fabrication of the ſmalleſt inſtruments.

Although caſt and forged iron be both of them extremely valuable, yet we find ſteel poſſeſs properties far ſuperior to either. The excellence of ſteel conſiſts chiefly in the great firmneſs of coheſion, and in the facility with which it may be tempered to any degree of hardneſs or of ſoftneſs, without having its ſtrength impaired. Steel of the beſt quality is prepared from the fineſt forged iron, by cementation with charcoal-duſt in a ſtrong heat. The bars of iron are imbedded in the charcoal-duſt, which lies in a ſtone-box raiſed from the floor on treſſels. Theſe boxes are placed in a kind of vaulted furnace, where a fire is kindled on the floor, which plays round them, and keeps them hot for ſome days. One end of the box has a hole in it, at which a bar can be occaſionally taken out, to obſerve what progreſs has been made in the converſion into ſteel. When that is complete, the fire is allowed to decay, ſo that the boxes cool gradually; which occupies a longer time than the cementation did. In this way forged iron is converted into ſteel. This mode of working is the moſt generally practiſed, and the moſt approved; though ſteel may be alſo made directly from crude iron by fuſing it with certain mixtures. Steel is accordingly made after this way in many parts in Germany. But it is obſerved, that all kinds of ores do not afford ſteel of equally good quality; ſo that the workmen call thoſe ores which yield the beſt ſteel, *ſteel ores.* In general, ſteel obtained by this proceſs is not ſo good as what is made in the ordinary way; ſo that we muſt be careful not to confound it with that ſort which is called *melted ſteel*, as this is prepared by fuſing ſteel made from bar iron; and the fuſion improves the quality, by favouring the eſcape of any heterogeneous matter, and by rendering every part of the grain of an equally fine texture.

After the ſteel is formed, it is made to receive a temper, by firſt rendering it perfectly hard, and then reducing it to the exact degree of ſoftneſs which the workman wiſhes it to retain. When ſteel is made red-hot in the fire, and then plunged ſuddenly into cold water, it becomes ſo exceſſively hard, that no tool is able to cut it: but if, inſtead of being inſtantly cooled, the ſteel is allowed to loſe its heat gradually, it then is found in the oppoſite extreme, and is perfectly ſoft: therefore, by combining theſe effects in different degrees, the ſteel may be brought to any temper the workman pleaſes. The firſt ſtep of the proceſs is to make the ſteel perfectly hard, and afterwards to ſoften it down to any temper we chooſe. The workman then gives the ſteel the hardeſt temper; next he returns it back to the fire, and gives it a gentle heat, if he means the hardneſs to be but little diminiſhed; if he intends to make it ſoft, he allows it to remain a longer time; and various tints of colour which heat makes ſteel to aſſume, enable the workman to judge of the temper with perfect exactneſs. In a gentle heat, ſteel acquires a yellow hue; next it becomes purple; then blue; and laſt of all, whitiſh grey, before all ſhades of colour vaniſh in a red heat. When the ſteel is removed from the fire, in the firſt ſtage it is extremely hard; in the ſecond, it is fit to be formed into tools for working upon metals; in the third, when blue, it becomes very pliant and elaſtic, and is of a proper temper to make ſprings, and to fabricate inſtruments for cutting all ſorts of ſoft materials. A bar of ſteel may be made to aſſume all theſe colours at once, by placing one end in the fire and keeping the other at a diſtance. As ſteel is the only ſubſtance from which tools can be made, it is not only highly uſeful, but it is moſt indiſpenſably requiſite, in the practice of every art; and it well deſerves the name of *mother of the arts*, which it has ſo often obtained.

Having thus endeavoured to exhibit a general view of the manufactures of iron through all the ſteps of the proceſs, it will in the next place be proper to attempt an inveſtigation of the cauſes which produce the difference between caſt iron, forged iron, and ſteel. In doing this, we ſhall follow chiefly the doctrine which M. Bergman delivers, in his Treatiſe on the Analyſis of Iron.

The firſt obſervation to be made is, that if there be a piece of each of the three preparations of iron, diſſolved in the vitriolic acid, the proportion of reſiduum left undiſſolved varies exceedingly in each of them; caſt iron containing the largeſt ſhare of inſoluble matter, ſteel the next, and forged iron leaſt of all; and that, of whatever foreign matters the reſiduum was compoſed, it always contained a portion of plumbago, upon whoſe properties the converſion of caſt iron into ſteel and malleable iron is to be explained. Plumbago is, from the lateſt examination, ſuppoſed analogous to ſulphur in its compoſition, or to be in reality nothing but a ſpecies of ſulphur compoſed of aërial acid and phlogiſton; the aërial acid combining into a ſolid concrete, to form plumbago, in the ſame way as vitriolic acid unites with phlogiſton in the formation of common ſulphur. The proof of this compoſition is derived from the analyſis of plumbago by Mr Scheele, who, in all his experiments, had reaſon to infer, that plumbago was a compound ſolely of aërial acid and phlogiſton, and that it was liable to a ſimilar reſolution and recompoſition with vitriolic ſulphur. It is therefore probable, that plumbago will be decompoſed, in all caſes where a third ſubſtance is preſented to its action, which attracts the phlogiſton more ſtrongly than the aërial acid does; then the plumbago will be decompoſed, the aërial acid will eſcape, and the phlogiſton will attach itſelf to the iron, and ſaturate every part of it which was not thoroughly metalliſed before. Now, in a vaſt variety of trials, M. Bergman conſtantly found, that caſt iron contained a large quantity of plumbago; ſteel, much leſs; and forged iron, ſcarcely any. He alſo found, that forged iron contained the largeſt ſhare of phlogiſton, caſt iron the leaſt, and ſteel an intermediate quantity. Here, then, we perceive, that the ſpecies of iron which contains the largeſt ſhare of plumbago, contains the ſmalleſt ſhare of phlogiſton; and that the ſpecies which is fully enriched with phlogiſton is quite purged of plumbago. From this circumſtance M. Bergman infers, that the difference between crude and forged iron conſiſts in the proportion of phlogiſton, and in the preſence or abſence of plumbago: crude iron is leſs rich in phlogiſton, and contains plumbago: forged iron is ſaturated with phlogiſton, and free from the adulteration of plumbago.

The internal change which takes place in the converſion of crude iron into forged iron, is ſuppoſed to ariſe from the decompoſition of the plumbago. The heat, diminiſhing the coheſion of the conſtituent parts of the plumbago, enables the phlogiſton to unite with the metallic earth, and expels the whole aërial acid. Thus the plumbago is decompoſed, and the crude iron ſupplied with a competent ſhare of phlogiſton. Before this decompoſition, the crude iron had been deficient in its quantity of phlogiſton ; in conſequence of it, it is provided with abundance, and brought to the ſame point of ſaturation with malleable iron : ſo that, according to M. Bergman, the decompoſition of plumbago, the expulſion of the aërial acid, and the adheſion of the phlogiſton to the impoveriſhed metal, changes crude iron into malleable iron.

In the formation of ſteel, this reſolution is not altogether ſo complete, though the metal has loſt part of the plumbago, and acquired a larger ſhare of phlogiſton ; for we muſt remember, that ſteel is in an intermediate ſtate between caſt and forged iron. Experiments, by ſolution in acids, ſhow, that ſteel contains more phlogiſton than caſt iron, but leſs plumbago ; and, on the contrary, that it contains leſs phlogiſton than forged iron does, but more plumbago. If, therefore, the proceſs of converting caſt iron into ſteel be ſtopped in the middle, we ſhall have a ſpecies of ſteel. Accordingly, caſt iron may be converted into ſteel by the mere application of heat. But as the fineſt ſteel is made from forged iron, it may be aſked, how the plumbago is to be found in the iron which contains none ? To ſay that it attracted plumbago ready formed, where none exiſted before, would moſt certainly be abſurd ; but to ſuppoſe that plumbago is regenerated by the union of its integrant parts, involves no contradiction. This is the conjecture employed to ſolve the difficulty. The aërial acid of the charcoal being expelled by the force of heat, combines with the redundant phlogiſton of the forged iron ; and this compoſes plumbago : and the iron being thus in part robbed of its phlogiſton, and at the ſame time furniſhed with plumbago, is converted into ſteel. All the experiments upon iron correſpond with this doctrine. M. Reaumur found, that, during the proceſs of ſoftening crude iron, the outſide, which was moſt expoſed to the heat, was completely changed into the nature of forged iron ; the intermediate ſtratum was converted into ſteel, while the more internal part was not affected in the leaſt.

Such is the outline of M. Bergman's doctrine, which is by far the moſt elegant and ingenious which has ever yet been offered upon the ſubject of the converſion of iron and ſteel ; and as ſuch deſerves much recommendation.

But perhaps M. Bergman's inveſtigation of the cauſe of the cold ſhort quality of iron is ſtill more ſucceſsful. It had long been queſtioned, whether this imperfection aroſe from ſome inherent defect in the nature of the metal itſelf, or from the admixture of ſome heterogeneous ſubſtance which debaſed the quality. M. Bergman obſerved, that a ſolution of cold ſhort iron in vitriolic acid, largely diluted with water, began in the courſe of a few hours to depoſite a white-coloured ſediment when the ſolution was expoſed to the acceſs of air. If this ſediment was collected before any ochry precipitate followed, it was diſcovered to poſſeſs properties peculiar to itſelf. By proper treatment with reducing fluxes, it was convertible into a new metal, totally diſtinct from any metal hitherto known. To this metal M. Bergman gave the name of *ſiderum*, from its intimate connection with iron. When any portion of this ſiderum was added to pure malleable iron, it became cold ſhort iron; and when the white calx was ſeparated from cold ſhort iron, it then became perfectly ductile. He alſo tried the mixture of other metals with iron, but found that none of them produced the ſame effect. So that it clearly appears, that the cold ſhort quality of iron is entirely owing to the alloy of ſiderum. The oppoſite quality of being red ſhort is not ſo eaſy to explain: and all we ſhall obſerve here is, that every kind of iron is ſubject to a great number of varieties, which it would not be proper to enter upon, as perhaps it would not be eaſy to ſet the whole in a clear point of view.

Yetlin diſſolved in vitriolic acid is of a greeniſh colour ſomewhat reſembling green glaſs, but a good deal lighter. This acid attacks yetlin even in the cold and without dilution; but the ſolution is promoted by adding two or three times its weight of water, and by the application of a boiling heat: a good deal of plumbago remains undiſſolved at the bottom. When precipitated by the cauſtic volatile alkali, it gives a calx of a very deep dark green colour, interſperſed with ſome greyiſh matter. The cauſtic fixed alkali throws down a light green calx.

Yetlin diſſolved in the nitrous acid is of a golden yellow colour. During their action a very copious ochry-like matter precipitates, which is of a brown red colour. This ſolution has a very ſtyptic taſte. Precipitated by the fixed alkali, it yields a reddiſh orange-like precipitate. The volatile alkali throws down a browniſh matter, ſomewhat of a yellow hue.

The marine acid attacks yetlin pretty violently: the ſolution is of a very light green. During their action the metal is ſplit often into thin ſlices, which remain undiſſolved. The acid takes up a good deal of the metal. Precipitated by the fixed alkali, a greeniſh matter falls, mixed with a little greyiſh matter. The volatile alkali throws down a deep green calx. Almoſt all the fixed air of the mild fixed alkali was abſorbed, ſcarcely any effervеſcence being raiſed.

The action of the vitriolic acid upon ſteel is not ſo violent as upon yetlin; but is increaſed by dilution and a boiling heat. The ſolution here is more complete, but a ſmall quantity ſtill remains undiſſolved. It is of a clearer colour than that of yetlin. Precipitated by the cauſtic fixed alkali, a green calx is thrown down; and by the vo-

volatile, an extremely deep green one, when viewed in the light; but when removed from the light, it appears tainted of a dark blue.

Steel is more ſoluble in the nitrous acid than yetlin is. The ſolution is of a yellow citron colour, ſomewhat inclining to red. A ſmall quantity of plumbago remains, of a blackiſh colour, as it is in the other two acids. Precipitated by the cauſtic fixed alkali, a yellowiſh citron-coloured matter is ſeparated. The volatile alkali precipitates it of a browniſh red.

Steel is not ſo eaſily acted upon by marine acid as yetlin is. The ſolution is of a lighter yellow than that of yetlin in the nitrous acid. The ſteel is likewiſe ſometimes ſplit into pieces, and there remains a good deal of a blackiſh brown matter undiſſolved. The cauſtic fixed alkali precipitates this ſolution of a moſt beautiful orange, and at the ſame time heightens the colour of the liquor. The volatile alkali cauſes a very dark brown precipitate, and the ſupernatant liquor is colourleſs.

Forged iron is the moſt ſoluble of the three kinds of iron in vitriolic acid; leaves ſcarcely any thing undiſſolved, and its ſolution is of the colour of that of ordinary green vitriol. It is not readily acted upon by the acid till it be properly diluted. When precipitated by the cauſtic fixed alkali, it gives an elegant green precipitate. The volatile alkali gives a copious calx, ſo green that it is almoſt black: ſometimes a whitiſh grey matter falls, which mixes with the green, and renders the whole of a faint blue tint.

Forged iron in the nitrous acid is of a deeper and more ochry yellow colour than ſteel in the ſame acid. It differs from that of yetlin, in its ſediment being of a browniſh ochry colour, without any appearance of red. Precipitated by the cauſtic fixed alkali, it gives a matter of a pretty orange yellow, which is at firſt preſently taken up, but by farther addition is again thrown down. The volatile cauſtic alkali throws down a ſeemingly more copious calx, which upon repoſe turned out of four different colours: the undermoſt part was of a brown colour, ſomewhat like the ochry ſediment; the next above it, black; the next, like the depoſition in the yetlin ſolution; and the uppermoſt, a dark browniſh red.

Forged iron diſſolves very well in the muriatic acid. The ſolution is of a very light green colour, inclining a little to yellow: a browniſh matter in ſmall quantity remains undiſſolved. The ſolution recipitated by volatile cauſtic alkali gives a calx almoſt wholly reſembling that ſeparated from the vitriolic ſolution, but is rather bluer. The cauſtic fixed alkali gives upon repoſe a deep green which inclines to black: a greeniſh yellow matter floats ſometimes a-top.

All theſe appearances are found to vary from the quality of the metal, and from the nature and purity of the acids and alkalis employed. All the precipitates of the different kinds of iron yield upon reduction malleable iron, and not the ſame kind of metal which was employed in ſolution.

LECTURE XXXIX.

Species 12. COPPER.

COPPER is an imperfect metal, of a brilliant enough red colour, called by the alchemiſts *Venus*. It has a diſagreeable ſmell, perceptible upon friction or being heated: its taſte is ſtyptic and nauſeous, leſs ſenſible, however, than that of iron. It is hard, very elaſtic, and ſonorous. It poſſeſſes a very great degree of ductility. It is made into very thin plates and wire of great length. It loſes about one-eighth or one-ninth of its weight in the hydroſtatic balance. It has ſo vaſt a tenacity, that a thread of it a tenth of an inch in diameter, is capable of ſupporting two hundred and ninety-nine and a half pounds weight before it break. Its fracture ſeems to be compoſed of ſmall grains. It is ſuſceptible of a regular form. M. l'Abbé Mongez defines its cryſtals to be quadrangular pyramids, ſometimes ſolid, and ſometimes compoſed of other ſmall ones adhering laterally.

In the earth, copper is found in different ſtates. Its ores are very numerous, and may be all referred to the following.

1. Native copper, of a red colour, malleable, and poſſeſſing all the properties of this metal. It is diſtinguiſhed into two kinds; copper of the firſt formation, and copper of the ſecond formation or of cementation. Copper of the firſt formation is diſperſed in laminæ or filaments in a matrix almoſt always quartzy. There are ſpecimens of it whoſe cryſtals imitate a kind of vegetation: others are in a maſs and in grains. The copper of cementation is generally in grains or laminæ, ſuperficially lying upon ſtones or iron. This laſt ſeems to have been depoſited in water charged with vitriol of copper and precipitated by iron. Native copper is found in ſeveral parts of Europe; at Saint-Bel in Lyonnois, at Norberg in Sweden, at Neuſol in Hungary, and in ſeveral countries in America.

2. Red copper: It is diſtinguiſhable by its red dull colour, reſembling that of the ſcales which are detached from copper reddened by the fire when it is ſtruck with a hammer. M. Monnet conſidered this ore as a natural calx of copper. It is generally mixed with native copper and mountain green. It is very rare, ſometimes cryſtalliſed in octagons or ſilky fibres, called *flowers of copper*.

3. Earthy copper, mountain green, or green chryſocolla. This ore is a true ochre of copper, of a more or leſs dull green, very light, unequally diſtributed in the matrix. It is ſometimes very pure. Three varieties of it are reckoned.

1. Simple mountain green, earthy or impure.
2. Mountain green cryſtalliſed, or ſilky copper of China. This kind, which is very common in Voſges and at Hartz, is alſo found in China: it is very pure, and cryſtalliſed in long ſilky very ſolid bundles.
3. Mountain green, in ſtalactites or malachite. This ſubſtance, which is very frequently found in Siberia, is compoſed of layers, which repreſent greater or ſmaller nipples: ſome ſpecimens are formed of needles, converging to a common centre. The different layers have not the ſame ſhades of green. Malachite is ſufficiently hard to receive a very fine poliſh. It is therefore uſed for making different toys.

4. Mountain blue, or blue chryſocolla. This is a calx of copper of a deep blue colour: it is ſometimes of a regular form, and in priſmatic rhomboidal chryſtals of a beautiful blue. In this ſtate it is called *azure copper*: at other times it preſents ſmall grains, depoſited in the cavities of different matrixes, and particularly in quartz. For the moſt part it is in layers, lying ſuperficially in the cavities of grey and yellow ores of copper. It appears that all theſe ores of copper have been precipitated from vitriolic ſolutions of copper by

means of calcareous earths, acroſs which theſe waters run. M. Sage conſiders theſe blue ores of copper as combinations of copper with the volatile alkali: and he ſays that they differ only in inſolubility. He believes that malachite is only an alteration of this blue, which he calls *azure tranſparent ore of copper.*

5. Copper united with ſulphur: yellow ore of copper, or coppery pyrites; for the naturaliſts uſe this name indiſcriminately: however, the miners uſe to call ores of copper, all the ſpecimens of copper united with ſulphur which are rich enough in metal to be ſmelted with advantage; and they reſerve the name of *pyrites* for the ſpecimens containing a great quantity of ſulphur and little metal. The rich ores of copper are generally of a brilliant yellow, inclining more or leſs to red or green. In the earth they form ſometimes conſiderable ſtrata. Oftentimes this copper is maſſy and dull; frequently ſcaly and micaceous. This is the form of the ores of copper from Denmark, Norway, Sweden, and Sainte-Marie-aux-Mines. At other times this ore is ſcattered up and down in its matrix, as the copper of Alſace: it is then called *tyger ore of copper.* This variety is mixed with a little azure. Frequently copper ores preſent at their ſurface very brilliant blue or violet colours, which are owing to the decompoſition of their principles. If theſe colours are only at their ſurface, they get the name of *copper cats-eye, azure*, or *peacock-coloured ores*; but if the colour penetrates deeper into the heart, they are called *white* or *violet vitreous copper ores.* They contain generally a large quantity of ſulphur, a little iron, and are not very rich in copper. When theſe kinds of ores are only ſuperficially ſcattered upon their matrix, they are called *pyrites:* theſe are the Derby ores in England, ſome of thoſe of Saint-Bel in Lyonnois, and ſeveral ores of Alſace, as thoſe of Caulenbach and Feldens; beſides, they are found adhering to all ſorts of matrices, to rock cryſtal, quartz, ſpar, ſchiſtus, mica, &c.

6. Grey copper ore, or Fahlertz of the Germans, is a combination of ſulphur and arſenic with copper, iron, and ſilver. It greatly reſembles the grey ore of ſilver: it is only a little leſs brilliant, and really differs from it only in containing leſs ſilver than it does. M. Romé de Liſle alſo diſtinguiſhes a white ore of ſilver, which he ſays contains a ſmall portion of ſilver more than the grey; but this is a true ore of ſilver.

7. The hepatic or brown ore of copper. This is a combination of iron, ſulphur, and copper. M. Romé de Liſle conſiders it as a changed grey copper ore, which has parted with the arſenic and a part of its ſulphur. He obſerves, that we muſt diſtinguiſh it well from the falſe hepatic copper ore; which he ſays is nothing elſe than a brown iron ore, and contains almoſt no copper.

8. Ore of copper, black or of a dirty colour. M. Gellert calls it *ore of copper in ſcoriæ*. It is a reſiduum of the decompoſition of the yellow and grey ores of copper, which contain neither ſulphur nor arſenic, and approach to the ſtate of malachite.

In eſſaying a copper ore, after its being pounded and waſhed, it muſt be long and ſtrongly roaſted, and then fuſed with four times its weight of black flux and ſome marine ſalt. A button of metal is found, which is frequently ſtill blackened by a little adhering ſulphur: it is fuſed with four parts of lead, and ſubjected to cupellation, to ſeparate the ſilver and gold, as there is but little copper which does not contain a certain quantity of theſe precious metals.

In the great copper-works the ores are pounded and waſhed: after that, they are roaſted at firſt in the open air, and almoſt without fuel; for as ſoon as the ſulphur which they contain begins to kindle, it continues to burn of itſelf. When it is extinguiſhed, the ore is roaſted afreſh once and again along with wood: after which it is fuſed acroſs coals, to get what is called the *impure copper*.

This ore as yet has loſt only a portion of its ſulphur. The fuſion it is ſubjected to, is intended to give the metal new ſurfaces, in order to facilitate its roaſting. It is ſubjected to ſix or ſeven roaſtings, according to the quantity of ſulphur contained, and is then fuſed to obtain the black copper. This copper is malleable: it is however ſtill combined with a little ſulphur, which is ſeparated in obtaining the perfect metals which it contains. The black copper is fuſed with three times as much black flux, which is called the reduction of the copper; and this mixture is moulded into the form of loaves, called *loaves of liquation.*

Theſe are placed upon two plates of iron, placed in ſuch a way that they leave a furrow between them. Theſe plates terminate the top of the furnace of liquation, whoſe bottom is inclined towards the fore-part. The fire, placed below the plates, heats the loaves: the lead fuſes, and falls through the coals, carrying along the ſilver and gold, which have more affinity with it than they have with the copper. After this operation, which is called *liquation*, the loaves are found conſiderably diminiſhed, and all deformed. They are expoſed to a ſtronger fire, ſo violent as to commence the fuſion of the copper, in order to ſeparate all the lead exactly. This third operation is called *reſſuage.* The lead, charged with the perfect metals, then undergoes cupellation. With reſpect to the copper, it is refined by fuſion in a crucible; in which it is left till all the heterogeneous matter it contains is ſeparated from it in the form of ſcum. It is tried by immerſing iron roads into it, which are thus covered with a little copper; and its purity is judged of according to its more or leſs brilliant red colour. The refined copper is run into plates, or ſeparated into *en roſettes.* For this laſt purpoſe, the ſcoriæ which cover the copper in fuſion are carefully removed: then the ſurface of the metal is allowed to fix. When it ceaſes to be fluid, a moiſt beſom is applied above: the impreſſion of the cold makes it contract; the portion which congeals detaches itſelf not only from the ſides of the crucible, but from the reſt of the fuſed metal, and is lifted off with pincers. Thus the greateſt part of the copper contained in the crucible is converted into *en roſettes*. The portion which remains at the bottom is called the *king*.

The pyrites of copper which contain little metal, are ſmelted only in order to extract the ſulphur and vitriol. They are roaſted and diſtilled for the ſeparation of the ſulphur. During the roaſting, a portion of vitriolic acid acts upon the metal, diſſolves it, and begins to form vitriol. The roaſted pyrites are then expoſed to the air; and when the vitrioliſation is finiſhed, the efloreſcent pyrites are waſhed, the ley filtrated; and by evaporation and cryſtalliſation, a blue rhomboidal ſalt is obtained, called *vitriol of copper*, *blue vitriol*, *blue copperas*, or *Cyprian vitriol*. It ſhall be taken notice of when we are examining the combinations of this metal.

Copper expoſed to the fire aſſumes colour in the ſame manner as ſteel does: it becomes blue, yellow, and at laſt violet. It does not fuſe till it is very red. When it is in proper fuſion, it ſeems to be covered with a green flame: it boils, and can be volatiliſed, as is obſerved in founders chimneys. Flowers of copper are alſo found in the crucibles in which it is fuſed. If this metal, in fine powder, is thrown acroſs flames, it gives them a blue and green colour. On account of this property, it is uſed in fire-works. If this metal, when fuſed, is allowed to cool ſlowly, and if, when the ſurface has become fixed, the ſtill fluid portion is decanted off, that part which ſtill adheres to the ſides of the crucible, or of the veſſel employed in this experiment, is found to be cryſtalliſed in form of pyramids; which are ſo much the larger and more regular, according to the more complete fuſion of the metal, and the management of its cooling.

The ſurface of copper which is heated with the concourſe of the air, burns and is changed into a calx of blackiſh red.

This calx is eaſily obtained, by reddening a copper plate, and then ſtriking it with a hammer: it falls off in the form of ſcales. The ſame thing happens if, after it has been made red, it is immerſed in cold water: the ſudden contraction of the parts of the metal facilitates the ſeparation of the calx covering the ſurface. This calx falls to the bottom of the water, and is called *ſcales of copper*. As this calx is not perfectly burnt, it may be calcined afreſh under a muffle: it then aſſumes a very deep brown red colour: urged with a violent fire, it fuſes into a blackiſh or brown cheſnut glaſs. The calx of copper may be decompoſed and deprived of the air, which changed its metallic properties by means of the vegetable or animal combuſtible bodies. The ſcales are in part reducible *per ſe*, ſince the founders, who purchaſe them from the braziers, think it ſufficient to throw them into great crucibles upon melted copper, with which they enter into fuſion and incorporate. They do the ſame with the filings.

The air acts upon copper the more eaſily when it is moiſt and altered: it is converted into a ruſt or green calx, which ſeems to have ſome ſaline qualities; for it has taſte, and is diſſolved by water: on this account the ancient chemiſts admitted a ſalt in copper. In this ruſt it is remarkable, that no part but the ſurface is attacked; and it ſeems even to ſerve for the preſervation of the interior parts of this metal, as we may learn from the ancient medals and ſtatues, which are very well preſerved under the coat of ruſt which covers them. The antiquaries call this cruſt *patine;* and value it greatly, becauſe it atteſts the antiquity of the pieces which it covers.

Water does not appear to attack copper unleſs it be converted into vapour: for this reaſon it is more dangerous to allow liquors to cool in copper veſſels, than to boil them in them; becauſe, as long as the liquor is boiling and the veſſel hot, the aqueous vapour does not attack its ſurface: it is quite the reverſe when the veſſel is cold.

Copper does not unite with the earthy matters: its calx facilitates their fuſion, and forms with them greeniſh glaſſes.

Lime and magneſia have no remarkable action upon copper; at leaſt the alterations occaſioned by them have not been much attended to.

The cauſtic fixed alkalis, digeſted in the cold with copper-filings, in a little time aſſume a very ſlight blue colour: the copper is coloured with a powder of the ſame colour. Theſe ſolutions are affected more eaſily in the cold than with heat, according to M. Monnet. It is eſſential, however, to obſerve, that this chemiſt tried theſe combinations with mild alkali, and not pure fixed alkali: this ſurely would have had a much greater action upon the copper.

The volatile alkali diſſolves this metal more rapidly. This ſalt, digeſted upon filings of copper, in a few hours gets a deep blue colour; it diſſolves, however, but very little of it. I obſerved the phenomena of this ſolution during a whole year. Into a ſmall veſſel I put ſome volatile cauſtic alkali upon copper filings: in a few months, the ſurface of the metal was covered with a blue calx; the ſides of the veſſel were covered with a pale blue calx; and the lower part of the veſſel, which contained the copper, preſented at the ſurface of the glaſs a brown calx, the top of which was yellowiſh. This liquor entirely loſes its colour when it is ſhut up: take out the cork, and it appears: it exhibits this phenomenon in a very remarkable degree only at the beginning, and when it is decanted off from above the copper. If the ſolution is old, and ſtill contains copper, its colour is a fine blue, although in cloſe veſſels; however, upon expoſure to air, it is much deeper. When this ſolution is ſlowly evaporated by means of fire, the greateſt part of the volatile alkali is diſſipated ; a portion remains fixed with the calx of the metal, and is depoſited in ſoft cryſtals, as M. Monnet has obſerved. M. Sage ſays, that very fine cryſtals may be obtained from it by a ſlow evaporation ; he compares them to the natural azure copper. However, this laſt does not give volatile alkali. When it is heated, it is not ſoluble in water ; is not efflorescent with the air, as that is which is prepared by art. M. Baumé ſays, that this compound forms very brilliant and beautiful blue cryſtals. This ſolution, expoſed to the air, dries very quickly, and leaves a matter of a graſs-green hue, which is juſt a calx of copper. M. Sage is of opinion that it is the origin of malachite. If an acid is poured into a ſolution of copper by the volatile alkali, no precipitate forms ; but the blue colour totally diſappears, and is changed into a very ſlight pale green. This phenomenon, which has been taken notice of by Meſſrs Pott and Monnet, ſhows that there is only very little calx of copper in the volatile alkali ; and that it is rediſſolved by the acid, or by the ammoniacal ſalt formed by the addition of the acid. The blue colour, however, may be reproduced by the addition of ſome volatile alkali to the mixture. The calx of copper made by means of fire, and all the other calces of this metal, are preſently diſſolved in the pure volatile alkali, which by this proceſs may be impregnated with a good quantity of metal. It quickly aſſumes the moſt beautiful blue colour ; and on that account is recommended as a teſt to diſcover the ſmalleſt portion of copper in all the matters in which it is ſuſpected *.

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* The changes of colour which the ſolution of copper exhibits from the admiſſion or excluſion of air, has attracted much notice from chemiſts on account of the beautiful appearance of the phenomenon. M. Bergman ſuppoſes, that the colour of the ſolution is intimately connected with the quantity of phlogiſton which the copper contains ; and that the only effect of admitting atmoſpheric air is to carry off a portion of phlogiſton from the metal : For it is to be obſerved, that if ſome filings of copper be put into a phial full of volatile

The vitriolic acid does not act on copper, unleſs concentrated and boiling. In the time of the ſolution, a great quantity of ſulphureous gas flies off. When it is over, a brown thickiſh matter is found, which contains the calx of copper and a portion of this calx combined with vitriolic acid. By ablution and filtration, a blue ſolution is obtained; if it is evaporated to a certain degree, and left to cool, it furniſhes long rhomboidal cryſtals of a beautiful blue colour, called *vitriol of copper*. If, inſtead of evaporating this ſolution, it is expoſed a long time to the air, it affords cryſtals; but a green calx is precipitated, a colour which all the calces of copper aſſume when formed or dried by the air *. The vitriol

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volatile alkali, and ſo cloſely corked as to exclude the acceſs of air, no ſolution will take place; becauſe volatile alkali cannot diſſolve copper perfectly ſaturated with phlogiſton; and the phlogiſton in this caſe has no poſſible means of eſcape, for want of the vehicle which air furniſhes. But if a ſmall quantity of air be included in the veſſel along with the volatile alkali and copper, a ſolution is made, which proves entirely colourleſs; but if the air gains free admiſſion, the ſolution becomes of a deep rich blue colour. We have it in our power to deſtroy this colour, by adding more copper and again excluding the air: and we muſt here remark, that the excluſion of air alone does not ſeem ſufficient to deprive the ſolution of all colour; at leaſt M. Waſſenberg kept ſome of it, hermetically ſealed in a glaſs tube, for nine months together, without being able to perceive any alteration. The explanation which M. Bergman offers of this change is, that the air, depriving the metal of phlogiſton, reduces it more completely to the ſtate of a calx, which exhibits a blue colour; that when only a ſmall quantity of air is admitted, the metal, being but partially robbed of phlogiſton, gives a colourleſs ſolution; and that when a deep-coloured ſolution is cloſely ſhut up with ſome freſh filings of copper, the ſolution becomes colourleſs, becauſe the volatile alkali is capable of diſſolving a larger proportion of copper when the metal contains more phlogiſton; therefore the volatile alkali attacks the metallic copper, which during ſolution parts with a ſhare of redundant phlogiſton to what was more calcined by the action of air; and thus reduces the whole to that degree of calcination which gives an uncoloured ſolution.

* Blue vitriol is ſeldom formed by diſſolving copper directly in the vitriolic acid. The blue vitriol of the ſhops is moſtly obtained from copper pyrites. It may alſo be made by ſtratifying plates

of copper has a very ſtrong ſtyptic taſte, approaching to cauſticity. When it is expoſed to the fire, it fuſes very quickly; it loſes its water of cryſtallization, and becomes of a blueiſh white. A very ſtrong heat is required for the ſeparation of its vitriolic acid, which adheres much more ſtrongly to copper than to iron. The vitriol of copper is decompoſed by magneſia and lime: the precipitate formed by theſe two ſubſtances is of a blueiſh white: if it is dried in the air, it becomes green; on this account ſome chemiſts ſay, that the precipitates of vitriol of copper are green. Abſolutely the ſame thing takes place with regard to thoſe obtained by the fixed alkalis in different ſtates: they are at firſt blueiſh, and aſſume a green colour upon drying: it is thus perhaps that mountain-green is formed. It is eſſential to obſerve, that when the vitriol of copper is precipitated by the ſolution of mild alkali, no efferveſcence is excited; which ſhows that the aërial acid combines very well with the calx of copper; a phenomenon which all metallic ſolutions do not exhibit. The volatile alkali likewiſe precipitates the ſolution of vitriol of copper of a blueiſh white colour; but the mixture very ſoon puts on a very deep blue, becauſe the volatile alkali diſſolves a portion of the copper precipitated: it alſo requires but very little of this ſalt to diſſolve all the calx of copper ſeparated from the vitriolic acid.

The nitrous acid diſſolves copper in the cold with rapidity. A great quantity of ſmoking nitrous gas flies off. It is the way which Dr Prieſtley uſed to get this gas in a very ſtrong ſtate. A portion of this metal, reduced to the ſtate of a calx, is precipitated in form of a brown powder: it is ſeparated by filtration. The ſolution, filtrated, is of a much deeper blue than that by the vitriolic acid; which ſhows that the copper is more calcined.

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copper with ſulphur, and cementing them together for ſome time; when the vitriolic acid of the ſulphur, being diſengaged, attacks and corrodes the copper, forming a metallic ſalt, which, by the affuſion of water, yields perfect cryſtals of blue vitriol.

calcined. If it is evaporated with precaution, it cryſtallizes by cooling. M. Macquer is one of the firſt chemiſts who have taken notice of this property, in his memoir upon the ſolubility of ſalts in ſpirit of wine. If its cryſtals are very ſlowly formed, they preſent elongated parallelograms: if they are depoſited more quickly, they are hexaëdral priſms, whoſe point is obtuſe and irregular; and they imitate bundles of diverging needles. And, laſtly, if the ſolution is very ſtrongly evaporated, it forms a maſs deſtitute of any regular form: this has undoubtedly been the reaſon why ſome chemiſts have ſaid, that this ſolution was incapable of cryſtallization. Nitrous copper is of a very bright blue colour: it has ſo cauſtic a taſte, that it might be uſed to corrode excreſcences which grow upon the ſkin. M. Sage ſays, that it is fuſible with a temperature of twenty degrees of Reaumur's thermometer. It detonates upon burning coals; but as it contains a great deal of water, this phenomenon is not very ſenſible. When it is fuſed in a crucible, it emits a great quantity of nitrous vapours, which might be collected by uſing a diſtilling apparatus. When it is dried, its colour is green: by a greater heat it becomes brown; and in this ſtate it is only a calx of copper. I have diſtilled it with a pneumatico-chemical apparatus; and got a great deal of nitrous gas, a little chalky acid, not an atom of pure air. It was reduced in this operation to the ſtate of a brown calx. Nitrous copper attracts humidity from the air; it may, however, be kept a long time in cloſe veſſels. In warm and dry air, it becomes covered with a green efflorеſcence. It is very ſoluble in water; a little more ſo in hot water than in cold. The ſolution, expoſed to the air in flat veſſels, or quickly evaporated in a dry and hot ſeaſon, leaves a green calx, as the cryſtals of this ſalt do in the ſame circumſtances.

It is precipitated by lime of a pale blue; by the fixed alkalis, of a blueiſh white; by the volatile alkali, in flocci of the ſame colour, which are very quickly diſſolved, and give a very brilliant deep blue colour; by the liver of ſulphur, of a reddiſh brown without hepatic odour; by the tincture of the gall-nut, of an olive-green. Vitriolic acid alſo decompoſes it; and we get cryſtals of blue vitriol, if this acid, in its very concentrated ſtate, has been employed. Stahl announced this decompoſition: M. Monnet has ſince confirmed it; and I have had occaſion to obſerve it ſeveral times. Iron has more affinity with moſt part of the acids than copper has. When a lamina of iron is immerſed into a ſolution of nitrous copper, the copper precipitates in its metallic form, and gilds the ſurface of the iron, either by reſuming the phlogiſton of this laſt metal, according to the Stahlian doctrine; or by yielding to it the air, which converted it into a calx, according to the pneumatic theory. Vitriol of copper preſents the ſame fact; and it is a proceſs made uſe of by ſeveral perſons, to induce the belief of its converſion into copper *.

The marine acid diſſolves copper only when it is concentrated and boiling. During this ſolution, only very little gas is produced, whoſe nature is unknown: it ſeems, however, to be inflammable gas. This acid aſſumes a very deep green and almoſt brown colour. This combination forms a maſs very ſoluble in water: if it is waſhed, the water is of a fine green colour, which diſtinguiſhes this ſolution from the two preceding. By ſlow evaporation and cooling it depoſites very regular priſmatic cryſtals if care has been taken: they form on the contrary only ſharp, very ſmall, and acute needles, when the evaporation has been too rapid and the cooling too ſudden. This marine ſalt of copper is of a very agreeable

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* The metallic ſalt formed by nitrous acid and copper exhibits a very beautiful appearance, when applied to the ſurface of tin-foil. If ſome of this ſalt be laid upon the tin-foil, gently wetted with water, and the tin-foil inſtantly rolled up, we ſoon perceive the action begin, firſt by the emiſſion of nitrous vapours, and then by the deflagration of the tin, which crackles and flames, and is left reduced into a grey calx. It requires celerity in rolling up the tin-foil to make the experiment ſucceed; and the cryſtals muſt at the ſame time be complete.

greeable graſs green: it has a cauſtic and very aſtringent taſte; it fuſes with a very gentle heat, and congeals into a maſs when left to cool. M. Monnet ſays, that there is a great degree of adheſion between its principles, and that the marine acid cannot be raiſed from it except by a very conſiderable heat: it ſtrongly attracts humidity from the air; it is decompoſable by the ſame intermedia with the preceding ſalts of copper. I have obſerved that the volatile alkali did not diſſolve ſo very well the calx of copper ſeparated from the marine acid, as it did that from the vitriolic and nitrous copper. The blue which it forms, is on that account not ſo lively; and there remains a portion of this calx which the volatile alkali does not diſſolve entirely. The vitriolic and nitrous acids do not decompoſe the marine ſalt of copper. The nitrous ſolution of mercury and ſilver decompoſe it, and are themſelves decompoſed in the inſtant of the mixture: a white precipitate forms by the junction of the marine acid with the mercury or ſilver, and the calx of copper unites with the nitrous acid. I have, however, obſerved, that the liquor does not aſſume the blue colour which the ſolution of copper by the nitrous acid ought to have; and that in general the calx of copper, formed by the marine acid, is very difficult of aſſuming this colour, as we have already ſeen with regard to the volatile alkali. It appeared to me, that in general the calces of copper paſs very difficultly from blue to green, and very difficultly too from green to blue. The marine acid diſſolves the calx of copper with a great deal more facility than it does the metal itſelf. This fact was accurately obſerved by M. Brandt. The ſolution is of a fine green, and cryſtalliſes as eaſily as the former; which proves, that in the metallic ſaline combinations, the metals are always in the ſtate of a calx, as we have already obſerved.

Nitre detonates with difficulty by means of copper. This ſalt muſt be fuſed, and the copper very hot, in order that the deflagration may take place; ſtill it is but

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very weak. This operation is peformed by throwing fine filings of copper upon nitre in fuſion in a large crucible, in order that the contact may be more multiplied. When the metal is very much heated, a ſlight motion, accompanied with ſomewhat rapid flaſhes, is perceived. The reſiduum is a calx of a grey colour, a little brown, mixed with the fixed alkali: it is waſhed; the water takes up the alkali, which retains a little copper, and the calx of this metal remains pure. It completely fuſes alone into a glaſs of a deep and opaque green: it is employed to colour enamels: the alkali is ſuppoſed to be rendered cauſtic; but there are no accurate experiments yet upon the ſubject.

Copper very eaſily decompoſes ſal ammoniac. M. Bucquet, who examined this decompoſition with great care, obtained, by making the experiment in a pneumato-chemical apparatus above mercury, from two gros of copper-filings and one gros of ſal ammoniac, fifty-eight inches of an claſtic fluid; of which twenty-ſix inches were very good alkaline gas, twenty-ſix were detonating inflammable gas, and ſix a mephitic gas, which extinguiſhed candles, without being abſorbed by water, or precipitating lime-water. There was diſengaged a little volatile alkaline ſpirit of a fine blue colour, which ſwam above the mercury. This experiment ſhows us that the marine acid produces inflammable gas by diſſolving the copper. The reſiduum was a maſs of a blackiſh green; the half of which was diſſolved by water, and communicated to it a fine green colour; a diſtinct character of the marine ſalt of copper: the other half was like a kind of calx of copper formed by the marine acid. Upon repeating this decompoſition in the doſe of four ounces of copper with two of ſal ammoniac with the ordinary apparatus of the balloon, M. Bucquet obtained two gros eighteen grains of a blue volatile alkaline ſpirit, which efferveſced with acids, and contained about an inch of chalky acid per gros. This chemiſt did not know how to account for this laſt gas: but I am of opinion that it might come from ſome impurities of the ſal ammoniac; for having repeated this experiment with ſal ammoniac prepared by ſublimation, I got a very cauſtic volatile alkali, not occaſioning the ſlighteſt effervefcence with acids. The calx of copper alſo decompoſes ſal ammoniac, and gives to the volatile alkaline ſpirit which it drives over a portion of aërial acid, which renders it effervefcent. This alkali is always blue, becauſe it carries over with it a ſmall portion of calx of copper, to which it owes this colour: however, the acids do not precipitate an atom of this metal. In pharmacy, two medicines are prepared with ſal ammoniac and copper; the firſt of which has received the name of *ammoniacal flowers of copper*, or *ens veneris*. This is nothing but ſome ſal ammoniac coloured with ſome calx of copper. A mixture of eight ounces of this ſalt with a gros of calx of copper, are made to ſublime in two earthen veſſels placed one above another. All the ſal ammoniac is volatiliſed without being decompoſed; and it attracts a little, which gives it a blueiſh colour. The ſecond preparation, called *aqua cœleſtis*, is made by digeſting ten or twelve hours a pound of lime-water with one ounce of ſal ammoniac in a copper baſon. The lime diſengages the volatile alkali, which diſſolves a little of the copper of the baſon, and which is coloured blue. Aqua celeſtis may be made in a glaſs or earthen veſſel, by adding a little filings or calx of copper to the lime-water and ſal ammoniac.

It ſeems that copper decompoſes alum: for if a ſolution of this ſalt is boiled in a copper-veſſel, a little clay is depoſited; and when this alum is precipitated by the volatile alkali, its earth aſſumes a ſmall blue colour, which detects the preſence of the copper.

The action of inflammable gas upon copper is not known. This metal unites with ſulphur very well. This combination may be made by the humid way, that is, by mixing flowers of ſulphur and filings of copper, and moiſtening the mixture with water; but it ſucceeds much better by the dry way. A mixture of equal parts of ſulphur and copper-filings is expoſed to the fire in a crucible, which is gradually heated till it be reddened; from this combination a maſs of a blackiſh grey reſults, a kind of coarſe copper, which is brittle and more fuſible than the copper. This compoſition is prepared for dyeing and painting Indian ſtuffs, by ſtratifying in a crucible laminæ of copper and ſulphur in powder, and heating the crucible as ſaid above: the reſult is pulveriſed, and called *æs veneris*. The liver of ſulphur and hepatic gas have a remarkable action upon copper: the former diſſolves it by the dry and humid way; the ſecond ſtrongly colours its ſurface; but their effects have not as yet been examined.

Copper alloys with ſeveral metals: With arſenic it becomes white and brittle, and forms the white tombac. It unites with biſmuth, and, according to M. Gellert, forms an alloy of a reddiſh white in cubical facets. It alloys very well with regulus of antimony, and gives a coppery regulus, which is diſtinguiſhable by a pretty violet colour. It decompoſes antimony, and unites with the ſulphur which it carries off from the regulus.

It combines very eaſily with zinc. This combination may be made in two ways. 1. By fuſion, a metal is obtained of the colour of gold, which is much leſs ſuſceptible of ruſt than the pure copper, but has leſs ductility. The more its colour reſembles gold, the more brittle is the metal: beſides, it varies according to the proportion of the mixture and the precautions obſerved in fuſing it. Its varieties are, ſimilor, pinchbec, Prince Rupert's metal, and gold of Manheim. 2. If laminæ of copper are cemented with lapis calaminaris, reduced into powder and mixed with charcoal, and it the crucible is reddened with the fire, the copper unites with the zinc, and forms braſs. This is leſs apt to ruſt than copper, it is as malleable and more fuſible than it; but when ſtrongly heated, it loſes the zinc, and becomes red copper *.

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* Although copper be extremely valuable on account of its ductility,

Copper is difficultly alloyed with mercury. A kind of amalgam, however, may be formed, by rubbing ſome very thin plates of copper with mercury. A plate of copper plunged into a ſolution of mercury by an acid,

tility, lightneſs, and ſtrength, it is rendered leſs uſeful on many occaſions from the difficulty of forming large maſſes of work. We cannot join heated bars of copper, by the operation of welding, as we can do thoſe of iron. Neither is it an eaſy matter to caſt copper ſolid, ſo that it ſhall retain all its properties entire: for if the heat be not ſufficiently great, the copper proves deficient in toughneſs when cold; and if the heat be raiſed too high, or continued for too great a length of time, the copper bliſters on the ſurface when caſt in a mould: ſo that the limits of fuſion at which copper will caſt well are exceedingly contracted; and from the intenſe heat neceſſary to make it flow with ſufficient tenuity, it becomes impracticable to regulate the degree of heat with exactneſs. From theſe circumſtances, pure copper is rendered leſs applicable to many different purpoſes. We find, however, that the addition of a certain proportion of zinc removes almoſt all the inconveniences, and furniſhes a mixed metal more fuſible than pure copper, extremely ductile and tenacious when cold, which does not ſo readily ſcorify in a moderate heat, and which is leſs apt to ruſt from the action of air and of moiſture. A mixture of this kind forms common braſs, which varies in its properties according to the proportion of the ingredients and the intimacy of their union. Braſs is frequently made by cementing plates of copper with calamine, when the copper imbibes one-fourth or one-fifth its weight of the zinc which riſes from the calamine. The proceſs conſiſts in mixing three parts of calamine and two of copper with charcoal-duſt in a crucible, which is expoſed to a red heat for ſome hours, and then brought into fuſion. The vapours of the calamine penetrate the heated plates of copper, and thereby add to its fuſibility. It is of great conſequence, for the ſucceſs of this proceſs, to have the copper cut into ſmall pieces, and intimately blended with the calamine. In moſt foreign founderies the copper is broken ſmall by mechanical means with a great deal of labour; but at Briſtol, the workmen employ a very ingenious method to reduce the copper into grains with more eaſe and celerity. A pit is dug in the ground about four feet deep, the ſides of which are lined with wood, and the bottom is made of copper or braſs, and moveable by means of a chain. The top is made of braſs with a ſpace near the centre, perforated with ſmall holes, through which the melted copper runs in a number of ſtreams into the water which the pit contains. The holes are luted with clay, and the water is perpetually renewed by a freſh ſtream, to prevent it from turning warm by the influx of melted copper.

acid, is covered with a fine argentine coat, owing to the ſemimetal being precipitated upon the copper.

Copper and lead unite very well by fuſion, as is proved by the loaves of liquation *.

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per. As the copper falls down through the cold water, it forms itſelf into grains, which collect at the bottom. In this form it can be moſt completely mixed with the powdered calamine. The difficulty of execution ariſes here from the violent exploſions which melted copper and water produce, unleſs every precaution be practiſed to prevent them. And even where no precaution is omitted, the works occaſionally explode with a degree of violence which endangers the lives of the workmen. Braſs is ſometimes made in another way, by mixing the two metals directly: but in managing this proceſs, a good deal of addreſs is requiſite, ſince the heat neceſſary to melt the copper, makes the zinc burn and flame, by which a conſiderable part is diſſipated; ſo that the remaining copper is defrauded of the due proportion of zinc. If the copper be firſt melted by itſelf, and the zinc heated and plunged into it, a ſtrong commotion enſues, though the diſſipation is much leſs conſiderable than in the other caſe, as the zinc is quickly imbibed by the copper, and in ſome meaſure protected and retained by it. If the copper and zinc be brought ſeparately into fuſion, and one poured upon the other, an exploſion happens, and a great part of the mixture is thrown about in drops, and loſt. The union appears to ſucceed beſt, and with the leaſt loſs of zinc, when fluxes containing inflammable matter are added to the mixture. The flux is firſt brought into fuſion in a crucible, the copper and zinc poured into it; and ſo ſoon as they appear thoroughly melted, they are to be well ſtirred together, and expeditiouſly poured out. The reaſon for pouring them out inſtantly, is to prevent the inflammation of the zinc, which would ſpeedily conſume, and leave nothing but red copper in the crucible. It is remarkable that either a large proportion of zinc or of copper give a metal reſembling the colour of gold, while in the intermediate proportions the imitation is not ſo good. Five parts of copper to one of zinc prove the beſt with an exceſs of copper; though, with an exceſs of zinc, the reſemblance to gold is ſtill ſtronger. But in this caſe the metal is extremely brittle; and indeed no braſs is made which bears extenſion when hot.

* When Archimedes endeavoured to determine the quantity of alloy in the crown of gold which Hiero king of Syracuſe gave him to examine, his calculations all proceeded on the ſuppoſition that the ſpecific gravity of the compound came out to be the exact mean between the gravities of the two metals of which it was compoſed. This was indeed the conjecture natural to form, without any previous know-

It is combined with tin in two ways; either by the application of fuſed tin to the copper, or by fuſing theſe two metals together. The firſt operation is uſed in the tinning of copper; the ſecond forms bronze. In tinning copper-veſſels, they are ſcoured well, in order to render their ſurface clean and brilliant; then they are rubbed with ſome ſal ammoniac to clean it entirely. They are heated, and ſome powdered reſin is thrown upon them. This ſubſtance, by covering the ſurface of the copper, hinders it from being calcined. Then the fuſed tin is laid on and ſpread with tow.

Several perſons complain, that the tinning of copper veſſels is not ſufficient to defend them from the action of the air, from humidity, and from ſalts; becauſe theſe veſſels are ſeen often covered with verdigris. It would be poſſible to remedy this inconvenience, by laying on a thicker coat of tin, if it were not apprehended that the ſuperior degree of heat to that of boiling water, to which theſe veſſels are frequently expoſed, might fuſe the tin, and render the ſurface of the copper expoſed. We are juſtly aſtoniſhed from the ſmall quantity made uſe of in tinning, ſince M. Bayen and M. Charlard have computed, that a copper pan, nine inches in diameter and three inches three lines deep, had acquired by tinning only
twenty

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knowledge of the ſubject to direct his judgment, though it is by no means conſonant to the truth of the fact, when aſcertained by experiment. So far from being true, we find no mixed metal correſpond accurately to the ſpecific gravity given by computation. Some mixtures exceed the mean, others fall below it. But the moſt ſingular of all diſcoveries is, that the ſpecific gravity of tin, mixed with copper, not only exceeds the mean gravity of the two metals, but even ſurpaſſes that of the heavieſt of them. A mixture, conſiſting of ten parts of copper and one part of tin, proves heavier than pure copper. The augmentation is alſo ſenſible when the lighter metal bears a larger proportion to the whole maſs. Even one part of tin to two parts of copper affords a mixture, poſſeſſing greater ſpecific gravity than the copper itſelf. This circumſtance has been long known, and is thoroughly eſtabliſhed: and the whole ſeries of facts upon the ſubject ſhows the fallacy of truſting to the ſpecific gravity of the mixed metal, as a juſt teſt of the proportion of ingredients which enter into the mixture.

twenty-one grains. However, this ſmall quantity is ſufficient to prevent the danger ariſing from copper, when attention is paid not to allow ſubſtances capable of diſſolving the tin, to remain long in the tinned veſſels; and chiefly when the tinning is frequently renewed, which the friction of the meat, the heat, and the actions of the ſpoons with which the ſubſtances cooked in them are agitated, very readily deſtroy. There is, however, a dread which we cannot ſhake off; I mean, the tin which the braziers uſe to tin the copper pans. It is frequently alloyed with a fourth of its weight of lead; and from this circumſtance we have reaſon to fear bad effects, as we know it is very ſoluble in acids and in fats. This ſhould render it neceſſary for government to form meaſures that the braziers be not deceived in the purchaſe of their tin; and that they employ only that of Malacca or of Banca in the ſtate it comes to us from the Indies, without its being alloyed and fuſed again by the pewterers.

M. de la Folie, a citizen of Rouen, celebrated for his chemical works relative to the arts, and for the uſeful diſcoveries with which he has enriched the arts of dyeing, and of making earthen-ware, and a great number of the manufactures of Rouen, has, in order to avoid the dangers and inconveniences from tinned copper, propoſed the uſe of veſſels of beat iron covered with zinc, which has nothing dangerous in it, as we have ſeen already. Several perſons have made an advantageous trade of it: it is to be wiſhed the number of ſuch veſſels were increaſed.

When tin is fuſed with copper, a more weighty metal reſults than the ſum of the two metals employed. This alloy is the more white, brittle, and ſonorous, according to the quantity of tin. When it is very white, it is called *bell-metal.* When it contains more copper, it is yellow, and is called *airain* or *bronze:* it is uſed for the caſting of ſtatues, and to make pieces of artillery, which ſhould be very ſolid, not to ſplit with the ſlighteſt impulſe; not very ductile, however, that they might not be deformed by the ſtroke of the bullets.

Copper and iron are ſuſceptible of combining by fuſion and ſoddering: however, this operation does not ſucceed eaſily. When a mixture of theſe two metals is fuſed in a crucible, the iron is found frequently ſown in the copper, without having contracted a perfect union. Copper decompoſes the mother-water of martial vitriol, though iron has a ſtronger affinity with the acids than copper has.

The uſes of copper are very multiplied and very well known. A multitude of various utenſils are made with it. It is particularly the yellow copper, or its alloy with zinc, which is moſt employed on account of its ductility and beauty. As copper is a very violent poiſon, it ought never to be adminiſtered in medicine. The moſt proper remedies, in caſes of poiſon by copper reduced to a calx or verdigris, are emetics, abundance of water, livers of ſulphur, alkalis, &c.

LECTURE XL.

Species 13. SILVER.

SILVER, called *Luna* or *Diana* by the alchemiſts, is a perfect metal, of a white colour, and of the moſt vivid brilliancy. It has neither taſte nor ſmell: its ſpecific gravity is ſo great, that it loſes about an eleventh of its weight in the hydroſtatic balance. A cubic foot of it weighs 720 pounds. It poſſeſſes ſo great a degree of ductility, that ſheets of it are made as thin as paper, and it can be drawn into finer wire than the hairs of our head. A ſingle grain can be made to contain an ounce of water. By its tenacity, a ſilver wire the tenth of an inch in diameter, can ſupport 270 pounds weight without being broken. Its hardneſs and elaſticity are inferior to thoſe of copper: It is the moſt ſonorous of the metals except copper: it ſtiffens under the hammer; of which property it may be deprived by nealing. Meſſ. Tillet and Mongez have cryſtallized it. They obtained quadrilateral pyramids, ſometimes iſolated like thoſe which are found on the ſides of the crucible in which it has been fuſed, or in groups adhering laterally to each other.

Silver is found in ſeveral ſtates in nature. The principal ores of this metal may be reduced to the following.

1. Native or virgin ore of ſilver. It is diſtinguiſhable by its brilliancy and ductility: its form is very various; it is frequently in irregular maſſes of different ſizes. Sometimes it is in the form of contorted capillary filaments: and in this ſtate ſeems to borrow its formation from a decompoſed red ore of ſilver, according to the obſervation of Henckel and M. Romé de Liſle. It is alſo found in laminæ like net-work, which the Spaniards call for that reaſon *arané;* like vegetation, or in branches, formed of octagons ſticking to each other. Some of theſe ſpecimens are like fern leaves; others again preſent iſolated cubes and octagons, whoſe angles are truncated: theſe laſt are the moſt rare. Native ſilver is almoſt always diſperſed in a quartzy matrix. It is found in Peru, in Mexico; at Konſberg in Norway, at Johan-Georgenſtadt, and at Ekenfriederſdorf in Saxony; at Sainte-Maria, and other places. This metal never has been found in the ſtate of a calx.

2. The vitreous ore of ſilver, according to the majority of mineralogiſts, is formed of ſilver and ſulphur. It is of a foul grey reſembling lead. The knife cuts it as it does lead. It is often without form, ſometimes cubical, having truncated angles. M. Monnet diſtinguiſhes one variety of it, which is converted into powder inſtead of being cut. This ore gives from 72 to 84 pounds in the hundred weight.

3. The red ore of ſilver is often deep in colour, ſometimes tranſparent, cryſtalliſed in cubes, whoſe ed-

ges are truncated, or in hexaëdral pyramids, terminated by three-ſided pyramids; it is called *roſſi-clero* at Potoſi. The ſilver is united with ſulphur and arſenic: it contains perhaps ſome aërial acid, ſince, by diſtillation, and the reception of the produce in a receiver lined with fixed alkali, M. Sage got cryſtals. When it is broken, its colour is clearer within, and it ſeems formed of ſmall needles or converging priſms like ſtalactites. If it is expoſed to a well-managed fire, capable of reddening it, the ſilver is reduced, and forms capillary vegetations reſembling native ſilver. It gives from 58 to 62 pounds in the hundred weight.

4. The grey and white ore of ſilver, which differs from the copper ore called *Fahlertz* only in its containing more precious metal. It is in maſſes, or rather triangular cryſtals, the ſides of which are cut *en biſeau* The thickeſt of theſe cryſtals are not of a very ſhining colour: the ſmalleſt ſcattered upon a flat matrix have a very agreeable appearance, on account of their very vivid brilliancy. The grey ſilver gives from two to five marks of ſilver in the quintal. Sometimes the grey ſilver is introduced into the organic ſubſtances, whoſe form it imitates exactly. It is then called *figured ore of ſilver;* ſuch is that which reſembles ears of corn, and which M. Romé de Liſle took for cones and ſcales of the pine tree: of this ſort alſo wood is found mineraliſed.

5. Black ore of ſilver, called *nigrillo* by the Spaniards, according to Meſſ. Lehman and Romé de Liſle, is only a decompoſition of the red or grey ore of ſilver, and a ſort of middle ſtate between that of theſe ores and native ſilver: this laſt is frequently found in it. The laſt mineralogiſt obſerves, that what is ſolid, ſpongy, or rotten, ſprings from the red and vitreous ores, and is much richer than that which is friable and of a pitchy colour, whoſe origin is owing to the alteration of the white or grey ores of ſilver. For this reaſon it is ſubject to vary in quantity of produce. It gives in ge-

neral from ſix or ſeven to near ſixty pounds in the hundred weight.

6. The horn ore of ſilver is of a dirty yellowiſh grey; ſometimes it inclines to a flax grey. It has, though rarely, a ſemitranſparency: if ſoft, may be bruiſed and eaſily cut: it fuſes with the flame of a candle. It is found cryſtalliſed in cubes, and moſt frequently it is without ſhape. It frequently contains portions of native ſilver. Mineralogiſts are not agreed about the nature of this ore. Some ſuppoſe it to contain ſulphur and arſenic. Meſſ. Lehman, Cronſtedt, and Sage, think that it is mineraliſed by the marine acid. It appears that this laſt ſentiment has been moſt generally adopted. M. Woulfe has confirmed it; and he aſſerts that ſilver and mercury are the only metals that are mineraliſed by the marine acid. M. Prouſt alſo owns this ſubſtance as a mineraliſer of theſe two metals.

7. Soft ore of ſilver of Wallerius is only native or mineraliſed ſilver, diſperſed in greater or leſs quantity in coloured earths. The gooſe-dung ore of ſilver, thus named on account of its yellow green mixed colour, is only a variety of this ſpecies.

8. Silver is found frequently combined with other metallic matters in the ores we have already deſcribed. Of this ſort is miſpickel, the grey ore of cobalt, kupfernickel, or ore of nickel; antimony, which preſents frequently the variety called *plumed ore of ſilver;* blende-galena, the martial pyrites, and white ores of copper: theſe laſt are alſo only grey ores of ſilver. All theſe ſubſtances frequently contain enough of ſilver to be ſmelted with profit; but it is eaſily conceived that they ſhould not be deſcribed as particular ores of ſilver, it being ſufficient to take notice that they are in part compoſed of this metal *.

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* M. Daubenton has very properly diſtinguiſhed the metallic ores by the number of metals which they contain, and has given marks for aſcertaining their preſence. This new method is much more accurate, ſure, and ſatisfactory, than that of former mineralogiſts.

The eſſaying of ſilver ores ſhould vary according to their nature. Thoſe which contain native ſilver require only to be pounded and waſhed. To ſeparate exactly this metal from the ſtrange ſubſtances which alter it, it may be triturated with crude mercury. This diſſolves the ſilver, and may be afterwards volatiliſed by means of fire, to get the perfect metal. The ſulphureous ores of ſilver require roaſting, and are then fuſed with a greater or leſs quantity of flux. In this fuſion the ſilver is obtained, generally alloyed with lead, copper, iron, &c. In order to ſeparate and know exactly the quantity of precious metal which this alloy contains, an entirely chemical proceſs is made uſe of, founded upon the properties of the imperfect metals. Lead, being capable of vitrification, and in its vitrification carrying along with it the imperfect metals, ſuch as iron, copper, without touching the ſilver; from this property a proceſs is employed to ſeparate the perfect metal from thoſe which alter it. The ſilver is fuſed with lead; which is in greater or leſs quantity according as it contains foreign ſubſtances: then this alloy is put into flat and porous veſſels, made with calcined bones and water. Theſe kinds of veſſels, called *cupels*, are proper to abſorb the glaſs of lead which is found in the cupellation. The ſilver remains pure after this operation. In order to know how much imperfect metal it contained, or of what title it was, any maſs of ſilver is ſuppoſed to be compoſed of twelve parts, called *marks*, and each of theſe weigh 24 grains. If the maſs of ſilver examined has loſt a twelfth of its weight, it is ſilver of eleven marks; if it has loſt only a twenty-fourth, the ſilver is eleven marks twelve grains fine; and ſo on. The cupel, after this operation, has acquired a great deal of weight: it is impregnated with the glaſs of lead, and with the imperfect metals which were alloyed with the ſilver, and which the lead has ſeparated from it. As the lead contains almoſt always a little ſilver, it is neceſſary to cupel it previouſly *per ſe*, in order to deter-

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mine the quantity which it contains: we muſt then deduct from the button, which is obtained in cupelling its ſilver, the ſmall portion which is known to be contained in the lead employed, which is called the *teſt*.

Cupellation preſents a phenomenon, from which the artiſt learns the progreſs of his operation. According as the ſilver becomes pure by the vitrification and ſeparation of the lead, it appears much more brilliant than the portion which is not ſo pure. The brilliant part increaſes by degrees; and when all the ſurface of the metal becomes pure and brilliant, the moment it paſſes to this ſtate, it exhibits a flaſh or a fulguration, which announces the completion of the operation. The cupelled ſilver is very pure relatively to the imperfect metals which it contained before: but it may contain ſome gold; and as it always contains a certain quantity of it, another proceſs is requiſite for the ſeparation of theſe two perfect metals. As gold is much more unchangeable than ſilver is by moſt of the menſtrua, the ſilver is diſſolved by the nitrous or marine acids and ſulphur; and the gold, upon which theſe ſolvents act but weakly, remains pure. This manner of ſeparating ſilver from gold is called *parting*. We ſhall ſpeak of the different ſorts of parting after we have explained the action of each of the ſolvents of ſilver employed, and when we come to treat of its alloy with gold. The great works for the extraction of ſilver from its ores, and for obtaining it pure, are nearly ſimilar to thoſe already deſcribed for the eſſay of the ores of this metal. In great, there are in general three ways of treating ſilver. The firſt conſiſts in triturating virgin ſilver with mercury. This amalgam is waſhed to ſeparate all the earth; it is preſſed through ſhamoy leather, and diſtilled in iron retorts. The ſilver is then fuſed and melted into ingots. This proceſs cannot be followed in the caſe of the ores which contain ſulphur; for that reaſon they are roaſted and mixed with lead, in order to refine the precious metal by cupellation. Such is the proceſs uſed for the rich ores of ſilver; as for the poor ones, a different method from the two firſt is followed. They are fuſed without a previous roaſting along with a certain quantity of pyrites. This fuſion, called *crude fuſion*, gives a maſs of copper containing ſilver, which is treated by liquation with lead: this laſt, which has carried along the ſilver during fuſion, is afterwards ſcorified by cupellation, and the perfect metal remains pure. Cupellation in great differs from that practiſed in ſmall, in this, that in the firſt the lead ſcorified is driven up from the cupel by the action of the bellows; whereas, in eſſaying, the glaſs of lead is abſorbed by the cupel *.

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* All the ſubſtances with which ſilver is minerallifed in its ore, may be ſeparated by fuſion with lead, which promotes the ſcorification of earths and imperfect metals, while it leaves the ſilver unaltered. The firſt part of the proceſs is to put one part of the ſilver-ore, well pulveriſed, into a veſſel along with eight parts of granulated lead. This veſſel is expoſed to a fire under a muffle, and the heat gradually increaſed. In a ſhort time the lead melts, and the pounded ore riſes up and floats a-top of it. A little after, the ore grows clammy, melts, and diſperſes to the ſides of the veſſel. At this period the fire is to be kept moderate, and then to be raiſed by degrees until the whole maſs has been brought into thin fuſion, and the ſurface of the lead be covered completely over with ſcoriæ. The operation is now finiſhed. The ſilver, during the fuſion, forſakes the earthy matters to unite with the lead, which collects with the whole of the ſilver into a maſs at the bottom, while the ſcoriæ ſwim a top without a particle of ſilver in them. It is ſometimes neceſſary to ſtir the matter with an iron rod; and if the ſcorification has been ſucceſsfully conducted, we find the rod, when cold, covered with a thin, ſmooth, ſhining cruſt, equally coloured on every ſide: but if, on the contrary, the ſcoriæ ſhow a conſiderable degree of clamminefs, adhere to the rod in quantity though it be quite red hot; if they be unequally tinged, ſeem duſty, and have rough grains interſperſed; you are certain that the proceſs is imperfect: for this is a ſign that the whole of the ore has not been converted into ſcoriæ; and therefore the ſilver cannot all precipitate with the lead to the bottom of the veſſel. This precipitation of the ſilver with the lead depends upon the attraction which ſubſiſts between the two metals, which diſpoſes them to join whenever they are brought into contact while fuſed, and upon the effect which the lead has to attenuate and promote the fuſion of the ſcoriæ; ſo that every particle of the ſilver may be ſet looſe from the matrix to precipitate with the lead into a metallic maſs. If the

Silver, obtained by the proceſſes juſt now mentioned, is in general much leſs alterable than all the metals hitherto deſcribed. Light, however long applied, makes no ſenſible change in its properties. Heat fuſes it, makes

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proceſs has ſucceeded according to our wiſhes, we have a diſtinct vitrefied maſs a-top, and a regulus at bottom, conſiſting of lead and ſilver. The proceſs is called *the precipitation of ſilver from its ore*, becauſe it is hereby detached from all earthy matters, and only left united with another metal, from which it is to be fuſed by a ſubſequent operation.

Once the ſilver is freed from all other impurities, and only diſperſed over a quantity of lead, we get clear of the lead by cupellation. The cupel muſt be previouſly heated red hot, to expel the moiſture completely: then the lead containing the ſilver is put into it; and the air having acceſs to the melted metal, which is placed under a muffle, the lead quickly calcines, and is converted into litharge. But as the converſion of lead into litharge is owing to the admiſſion of air, there muſt be a proviſion for the removal of what is already formed; otherwiſe it would collect on the ſurface, and protect the reſt of the lead from undergoing the ſame change. Now this inconvenience is provided for by making the cupels of ſuch ſpongy materials as will completely imbibe all the liquid litharge as it forms: ſo that in the proceſs of cupellation the litharge is perpetually entering the body of the cupel, until the whole lead be abſorbed, and the button of ſilver left purified on the top. There is here ſome nicety in regulating the heat: for, if it be too low, the litharge does not ſufficiently liquefy and penetrate the cupel; and if too great, the litharge penetrates the cupel ſo rapidly as not to have time to ſcorify any heterogeneous matter which may ſtill adhere to the ſilver. In a ſucceſsful eſſay, the ſurface of the metal ſhould appear convex and more red than the cupel; the ſmoke ſhould riſe almoſt to the top of the muffle; the middle of the eſſay ſhould be ſmooth, and ſurrounded by a ſmall circle of litharge, which is continually imbibed by the cupel. As the cupellation advances, the fire requires to be increaſed, becauſe ſilver is more difficult to fuſe, and helps to protect the lead. When the whole lead is abſorbed, we perceive a ſudden corruſcation of the ſilver, which ariſes from the congelation of the ſurface; and the workmen ſay that it *lightens*. At the ſame time, we often ſee efloreſcences ſhoot from the ſilver in different directions, termed the *vegetation of the button*. This appearance is produced by the contraction of the ſolid ſhell of ſilver, which ſqueezes out the melted matter in the centre through little cracks and crevices. In order to prevent this accident, which ſometimes occaſions a loſs of metal, it is neceſſary to increaſe the heat, to keep the ſilver ſtill in fuſion, and to allow it to cool and to conſolidate gradually. The

conit boil, and volatilſes it, but without alteration. A white heat is requiſite for its fuſion; it is more fuſible than copper. When it is kept in fuſion for ſome time, it bubbles up and emits vapours, which are nothing but volatiliſed ſilver. This fact is proved by its being found in the vents of chimneys in which great quantities are continually fuſed. It is confirmed by the experiment of Meſſrs the Paris Academicians: By expoſing very pure ſilver to the focus of M. Trudaine's lens, theſe gentlemen ſaw this metal, when fuſed, emit a thick ſmoke, and whiten a gold plate which was expoſed to it.

Silver, by cooling ſlowly, is capable of a very regular form, or of cryſtallizing into quadrangular pyramids. M. Baumé had already obſerved, that it aſſumed a ſymmetrical form, which was evident at its ſurface from filaments reſembling the down-hair of feathers. I have obſerved, that the pure button obtained by cupellation, exhibited frequently at the ſurface ſmall ſpaces with five or ſix ſides put between them like windows: but the cryſtallization in pyramids has been obſerved only by Meſſrs Tillet and l'Abbé Mongez.

It has been for a long time believed, and ſome chemiſts ſtill think, that ſilver is indeſtructible by the combined action of heat and air. It is ſo far certain, that kept in fuſion with the contact of air, it does not appear to be ſenſibly altered. However, Juncker has advanced, that by long reverberation, according to Iſaac de Hollandors's way, the ſilver was changed into a vitreſcent calx. This experiment was confirmed by M. Macquer. This learned chemiſt expoſed ſome ſilver, twenty-four times ſucceſſively, in a porcelain crucible, to a fire which

continuance of the heat alſo permits any litharge which may lie under the button to enter the cupel; ſo the whole is completely abſorbed, and nothing but ſilver left in a metallic form. There are ſome ſmall variations requiſite when the ore contains iron, tin, or copper. The mode of working in large is conducted upon the ſame principles, and is almoſt the ſame in every particular.

bakes that of sèves; and from the twentieth fuſion he obtained a vitriform matter of a green olive, which ſeemed to be a true glaſs of ſilver. This metal, when heated with the focus of a burning lens, always preſented a white powdery matter at its ſurface, and a greeniſh vitreous covering on the ſupport upon which it was placed. Theſe two facts cannot leave a doubt of the changeability of ſilver: though it be much more difficult of calcination than the other metallic ſubſtances, it is nevertheleſs ſuſceptible of converſion in time into a white calx, which, urged with a violent fire, gives an olive-coloured glaſs. Perhaps it might be poſſible to obtain a calx by heating this metal when reduced to very fine laminæ in a matraſs, as it is done in the caſe of mercury.

Silver ſuffers no change from the atmoſphere: its ſurface is but very little tarniſhed even though it be long expoſed; nor has water any action upon it. The earthy ſubſtances do not combine with it: it is probable that its calx would give an olive colour to glaſs with which it was made to enter into fuſion. The ſaline earthy matters and the alkalis have no ſenſible action upon ſilver; nor has great attention been paid to this ſubject.

The vitriolic acid diſſolves ſilver when it is very concentrated and boiling, and when the metal is in a ſtate of great diviſion. A great quantity of ſulphureous gas is emitted from the ſolution: the ſilver is reduced to a white ſubſtance, upon which we muſt pour ſpirit of vitriol to obtain a ſolution. By evaporation very ſmall needles of vitriolum lunæ cryſtalliſe. This ſalt fuſes with heat: it is very fixed: it is decompoſable by the alkalis, iron, copper, zinc, mercury, &c. All the precipitates obtained may without addition be reduced into fine ſilver in cloſe veſſels.

The nitrous acid diſſolves ſilver with rapidity, and even without the aſſiſtance of heat. This ſolution goes on ſometimes ſo rapidly, that to prevent its inconveniences, the ſilver is obliged to be employed in a maſs.

A great deal of nitrous gas is diſengaged, and a more or leſs copious white matter precipitates, if the ſpirit of nitre contain any portion of vitriolic or marine acid. The nitrous acid is generally coloured blue or green: it loſes this colour, and becomes tranſparent when the ſolution is finiſhed, and pure ſilver has been employed: but when the ſilver contains copper, there is a greeniſh ſhade more or leſs. Frequently the pureſt ſilver that can be employed contains ſome gold: then as the nitrous acid has but a very little action upon gold, as it acts upon the ſilver, the gold is ſeparated from it in ſmall blackiſh flocci, which collect at the bottom of the veſſel, and are pure only gold unaltered.

From this different action of the nitrous acid upon theſe two metals, it is ſucceſsfully employed for their ſeparation in the operation of parting by aqua fortis. The nitrous acid can take up more than the half of its weight of ſilver. This ſolution is very cauſtic: it ſtains the epidermis black, and entirely corrodes it *. When it is very copious, it depoſites ſmall brilliant cryſtals like ſedative ſalt: by evaporation to half its quantity, it gives, by cooling, flat cryſtals, which are either hexagons, triangles, or ſquares, and which ſeem formed of a great number of ſmall needles adhering ſidewiſe. Theſe laminæ are placed obliquely upon one another. They are tranſparent and very cauſtic; called *nitrum argenti*, *nitrum lunare*, *cryſtalli lunæ*. This ſalt is readily altered by the contact of the light, and blackened by combuſtible vapours. If it is put upon a burning coal, it detonates, and leaves a white powder, which is pure ſilver. It is very fuſible. If it is expoſed to the fire in a crucible, at firſt it bubbles up upon loſing the water of its cryſtals; then it remains in tranquil fuſion. If in this ſtate it is left to cool, it forms into a grey maſs, having ſlightly the appearance of needles, and forms a preparation known in pharmacy and ſurgery by the name of *lapis infernalis*. It is not neceſſary to uſe cryſtalli lunæ, which are very tedious to make and very expenſive; it is ſufficient to evaporate to dryneſs a ſolution by the nitrous acid, to put the reſiduum into a crucible or ſilver veſſel, as M. Baumé directed, and to heat it ſlowly till it be in perfect fuſion; then it is run into ingot molds, to give it the form of ſmall cylinders. If the ſticks of lapis infernalis are broken, it is obſerved that they are formed of needles, which divide in rays from the centre, ſeeming to terminate at the circumference. The nitrum lunare, in the preparation of the lapis infernalis, muſt not be long heated: without this precaution, a part of it is decompoſed, and a button of ſilver is found at the bottom of the crucible.

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* Beſides ſtaining the ſkin, the ſolution of ſilver in nitrous acid ſtains vegetable matters, and many kinds of ſtone. It is now uſed to mark linen for the bleachfield, where the proceſs of bleaching, inſtead of effacing the colour, increaſes the deepneſs of the ſhade. This additional ſtrength of colour proceeds from the influence of the ſun's light upon the metal in the ſalt, to which it furniſhes phlogiſton; and if any part be ſhaded from the ſun, it will remain colourleſs. When agates and other ſtones are ſtained, they muſt alſo be expoſed to the light before the ſolution makes any change. It is clear that the ſilver acquires phlogiſton, as in ſome caſes metallic particles are revived merely by expoſure to the rays of the ſun. From the corroſion of the ſkin by lunar cauſtic, the detached phlogiſton adheres to the ſilver and gives the deep colour.

In order to obſerve what paſſes in the operation, I diſtilled cryſtalli lunæ in a pneumato-chemical apparatus. They gave me ſome nitrous gas, and a great quantity of dephlogiſticated air, the pureſt that I know. In my matraſs I found the ſilver entirely reduced; the glaſs had put on the opacity of enamel, and was of a fine marrone brown colour. This brown colour is ſurely owing to manganeſe or ſome other ſubſtance contained in the glaſs; for the colour of the glaſs, formed by the calx of ſilver, inclined to an olive green, as has been already obſerved.

Nitrum lunare expoſed to the air does not attract humidity; it very eaſily diſſolves in water, and may be cryſtalliſed by a ſlow evaporation.

The nitrous ſolution of ſilver is decompoſed by the ſa-

ſaline earthy and alkaline ſubſtances; but with very different phenomena, according to their ſtate. Lime-water forms a very copious olive precipitate. The aërated fixed alkalis precipitate it white; the cauſtic volatile alkali, of a grey inclining to an olive-green. Although the nitrous acid has manifeſtly the ſtrongeſt action upon ſilver, it has not the greateſt adheſion and affinity with it: the vitriolic and marine acids are capable of carrying off the ſilver with which it is combined. For that reaſon, by pouring a few drops of theſe acids into a nitrous ſolution of ſilver, a precipitate in a white powder is formed when the vitriolic acid is uſed; and in thick flocci, like a coagulum, by the uſe of the marine. In the firſt caſe, vitriolum argenti is formed; in the ſecond, a marine ſalt of ſilver. Theſe two ſalts, not being very ſoluble, are precipitated. It is not neceſſary to uſe the vitriolic and marine acids, uncombined, to effect theſe decompoſitions; for this purpoſe, the neutral ſalts, reſulting from their union with the alkalis and earths, may be employed: hence a double decompoſition and combination takes place; the nitrous acid ſeparating from the ſilver, unites with the baſe of the vitriolic and marine ſalts.

Upon this difference of relation between the acids and ſilver, a proceſs is formed, which is uſed to obtain a very pure nitrous acid, exempt from the mixture of other acids, and ſuch as is required in ſeveral metallurgical operations, and in moſt part of chemical inveſtigations. As, in diſtilling nitrous acid, it rarely happens that a certain part of the vitriolic or marine acid does not come over along with it, chemiſts have found methods of ſeparating theſe foreign fluids; and for this purpoſe make uſe of the nitrous ſolution of ſilver with great advantage. A nitrous ſolution of ſilver is poured into the impure nitrous acid, till no farther precipitation is occaſioned: the precipitated vitriol of ſilver, or horn-ſilver, is allowed to ſubſide; the acid is poured off, and diſſolved with a gentle heat, to ſeparate the ſmall portion of lunar ſalts which it may contain. What is obtained is very pure nitrous acid; it is called *aqua-fortis præcipitata.*

The greateſt part of the metals are capable of decompoſing the nitrous ſolution of ſilver, in conſequence of their ſuperior affinity with the nitrous acid. The arſenical neutral ſalt, diſſolved in water, produces, in a nitrous ſolution, a reddiſh precipitate, formed by the union of the ſilver with the arſenic. This precipitate imitates the red ore of ſilver. Silver is obtainable in its metallic ſtate by precipitation with moſt of the metals and ſemimetals; but as the ſeparation only of this perfect metal by means of mercury and copper is of any importance, it is to be conſidered here on account of the phenomena of the firſt and the utility of the ſecond.

Silver, ſeparated from the nitrous acid by means of mercury, is in its metallic ſtate; and the ſlowneſs of its precipitation gives riſe to a particular ſymmetrical arrangement, called *arbor Dianæ*, or *arbor philoſophorum.* There are ſeveral proceſſes for obtaining this cryſtallization. Lemery directed an ounce of fine ſilver to be diſſolved in moderately ſtrong nitrous acid; which ſolution is to be diluted with about twenty ounces of diſtilled water; then two ounces of mercury are to be added. In forty days, a very beautiful vegetation forms. Homberg has given a much ſhorter proceſs. An amalgam, made in the cold with four gros of ſilver in thin plates, and two gros of mercury, is diſſolved in a ſufficient quantity of nitrous acid; to this ſolution a pound and a half of diſtilled water is added. Into an ounce of this liquor a ſmall ball of a ſoft amalgam of ſilver is immerſed, and the precipitation of the ſilver almoſt inſtantly takes place. The precipitated ſilver, united with a portion of mercury, falls in filaments, as if priſmatic, upon the ſurface of the amalgam; other filaments lay themſelves upon the firſt, in ſuch a manner as to imitate a vegetation in form of trees. Laſtly, M. Baumé has deſcribed a method of obtaining Diana's tree; in which there is a little difference from Homberg's berg's proceſs, and which ſucceeds more certainly. He directs mixing ſix gros of a ſolution of ſilver, and four gros of a ſolution of mercury, by the nitrous acid, both ſaturated, and to add to them five ounces of diſtilled water, and to pour them into a glaſs veſſel upon ſix gros of an amalgam, made with ſeven parts of mercury and one of ſilver. Theſe two methods ſucceed with much more readineſs than thoſe of Lemery, by the reciprocal action and relation between the metallic ſubſtances. The mercury contained in the ſolution attracts that of the amalgam; the ſilver contained in this laſt alſo acts upon that contained in the ſolution; and from theſe attractions a more ready precipitation of the ſilver takes place. The mercury which makes part of the amalgam being more abundant than would be neceſſary to precipitate the ſilver from the ſolution, produces a third effect of very important conſideration: it is that which attracts the ſilver, by the affinity and tendency which it has to combine with this metal: it effectually combines with it, Diana's tree being only a brittle cryſtalliſed amalgam. This cryſtallization ſucceeds much better in conical veſſels, as of glaſs, than in round or wide veſſels, ſuch as the cucurbit recommended by M. Baumé. It is found alſo neceſſary to keep the veſſel in which the experiment is made, from agitation, which might oppoſe the ſymmetrical arrangement of the amalgam.

Copper, put into a ſolution of ſilver, likewiſe precipitates this metal in its brilliant and metallic form. This proceſs is generally employed to ſeparate the ſilver from its ſolvent, after the parting is finiſhed. Copper plates are ſteeped in the ſolution, or rather the ſolution is put into copper veſſels: the ſilver inſtantly ſeparates in tufts of a whitiſh grey colour. The liquor is decanted when it is blue, and no more ſilver precipitates. The ſilver is waſhed with ſeveral waters: it is fuſed in crucibles, and then ſubmitted to cupellation with lead, to ſeparate a portion of copper to which it is united in the precipitation.

tion. The ſilver thus procured is the pureſt of all: it is twelve marks fine. From theſe two precipitations by mercury and copper, it is clear, that the metals, ſeparated from their menſtrua by metallic ſubſtances, are precipitated with all their properties *.

The marine acid, in its ſtate of fluidity, does not immediately diſſolve ſilver; but it appears very ſuſceptible of diſſolving it when in the ſtate of a gas; as the operation of the concentrated parting ſhows, which conſiſts in expoſing to the fire golden laminæ alloyed with ſilver, cemented with a mixture of martial vitriol and common ſalt: the vitriolic acid diſengages the ſpirit of ſalt, which directs its action to the ſilver, and diſſolves it. The following is a much more ready and more eaſy proceſs for combining the marine acid with ſilver. Some ſpirit of ſalt is poured into a nitrous ſolution of ſilver: the very copious precipitate which is inſtantly formed, is the combination of the marine acid and ſilver, which has a greater affinity with it than with that of nitre, and which conſequently quits this laſt to unite with the marine. The ſame combination is obtainable by pouring ſome marine acid into a ſolution of vitriol of ſilver; becauſe this acid has a greater affinity with the metal than the vitriolic has. The marine acid may alſo be combined with it, by heating it upon a calx of this metal precipitated from the nitrous acid by fixed alkali.

The marine ſalt of ſilver has ſeveral properties which it is of importance to know. It is remarkably fuſible. When it is expoſed in a phial to a gentle fire, as upon

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* When the ſilver is precipitated from acid of nitre by means of copper, we find that one part of copper is ſufficient to precipitate three parts of ſilver, and to ſaturate all the acid which held the ſilver diſſolved. In this caſe, moſt authors obſerve, that the ſilver is not quite pure, but contains a ſmall quantity of copper; as indeed, in almoſt all precipitations, ſome of the precipitant adheres to the precipitate. The ſilver is found, in a metallic ſtate, divided into extremely minute particles; and upon this account employed in cold ſilvering, where the ſilver is applied to the ſurface of other metals by means of detergent ſalts, which clear them of all impurities.

hot cinders †, it fuſes into a grey ſemitranſparent ſubſtance, very ſimilar to horn; and for that reaſon it is called *luna cornea*. If it is run upon a porphyry, it fixes into a friable ſubſtance, as if cryſtalliſed into argentine needles. If it is long heated with the contact of air, it is decompoſed: it eaſily paſſes through the crucibles; a part is volataliſed, and another is reduced into metals, and gives globules of ſilver, ſet in the portion of luna cornea not decompoſed. Luna cornea, expoſed to the air, loſes its white colour, and very ſoon turns brown. It diſſolves in water but in very ſmall quantity; ſince a pound of boiling diſtilled water takes up three or four grains, according to experiments of Monnet. The alkalis are capable of decompoſing luna cornea diſſolved in water, or treated with heat, along with theſe ſalts: this is a means employed for obtaining the pureſt and fineſt ſilver which we know. A mixture of four parts of fixed alkali, and one of luna cornea, is put into a crucible, and fuſed: when it is in proper fuſion, it is taken from the fire, left to cool, and broken: the ſilver is ſeparated, which is found below the febrifugal ſalt formed by the operation, and the ſuperabundant alkali employed. M. Baumé, the author of this proceſs, ſays, that the quantity of alkali which he preſcribes prevents the luna cornea from paſſing through the crucible, by acting upon all its parts, which it decompoſes at once. M. Margraaf has obſerved, that the concrete volatile alkali, when mixed with luna cornea, does not decompoſe it, but that it unites without precipitating the ſilver. This combination ſeems to reſemble the ſal alembroth, according to M. Macquer. The Berlin chemiſt juſt now mentioned has given another proceſs for the reduction of luna cornea, and for obtaining the ſilver perfectly pure. Five gros ſixteen grains are triturated in a mortar, with an ounce and a half of concrete volatile alkali, making an addition of as much water as will form a paſte: the mixture is ſtirred till the effervefcence ceaſe; then three ounces of very purified mercury are added; and the whole triturated till we perceive a fine amalgam of ſilver: it is waſhed with water, then triturated, and the waſhing renewed, till the water come off clear, and the amalgam be very brilliant; then this laſt ſubſtance is dried, and diſtilled in a retort, till the veſſel be of a white red: the mercury paſſes over into the receiver, and the ſilver is found pure at the bottom of the retort. In this way ſilver is obtained in perfect purity, and without any ſenſible loſs. It is this ſilver which ſhould be uſed for delicate chemical experiments. The water made uſe of for waſhing the mixture has taken along with it two ſubſtances; a certain quantity of ſal ammoniac, which it holds in ſolution, and a white powder, which it cannot diſſolve. When this powder is ſublimed, a ſmall quantity of ſilver is found at the bottom of the ſubliming veſſel. This experiment proves, that luna cornea is not completely decompoſed except by means of a double affinity; and in fact, in Margraaf's proceſs, the volatile alkali unites with the marine acid, only becauſe the ſilver combines upon its part with the mercury, which attracts and ſolicits it to quit the acid, which the alkali alone cannot effect. But it is evident, that this tedious and expenſive operation cannot be made uſe of except in ſmall, as in our laboratories. If luna cornea were to be reduced in great quantities, either the fixed alkalis, or ſome of the metallic ſubſtances, would be employed, the moſt part of which has more affinity with the marine acid than ſilver has. Among the reſt of this ſort, are regulus of antimony, lead, tin, and iron, &c. If one part of luna cornea, and three of any other ſubſtances, are mixed in a crucible, the ſilver is found reduced at the bottom of the crucible, and the metal employed, united with the marine acid, above it. The ſilver thus ſeparated is very impure. It contains always a portion of the metal uſed for reduction; and as lead, which is directed by Kunckel, is moſt generally employed, the ſilver thus obtained requires cupellation; and by this means never can be brought to that purity of which it is capable by the alkalis or Margraaf's proceſs.

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† It is proper to call to mind here, that the moſt part of the metallic combinations with marine acid exhibit this property. Many of them are in fact fuſible enough to merit the name of *butters*, which has been given them by chemiſts; ſuch are the butters of arſenic, biſmuth, antimony, zinc, and tin, &c.

Aqua regia acts very well upon ſilver, which precipitates as the ſolution goes on. This effect is very eaſily conceived: the nitrous acid firſt diſſolves the ſilver which is taken from it by the marine, forming luna cornea, which is depoſited on account of its little ſolubility: in this way may ſilver be ſeparated from gold.

The action of the other acids upon ſilver is not well known; only that a ſolution of borax produces a very copious white precipitate in a ſolution of this metal in nitrous acid, which is owing to a combination of ſedative ſalt and calx of ſilver.

This metal ſeems to be unalterable by the neutral ſalts; at leaſt it is ſo far certain, that it does not detonate with nitre, nor decompoſe ſal ammoniac. This unalterability of ſilver by nitre furniſhes a good way of getting rid of the imperfect metals which may happen to be united with it by means of their calcination; ſuch as copper, lead, &c. The ſilver too much alloyed is fuſed with nitre: this ſalt detonates, and burns the imperfect metals; and the ſilver is found at the bottom of the crucible: it is much purer than it was before.

Almoſt all the combuſtible matters have a more or leſs remarkable action upon ſilver. No metal is more quickly tarniſhed by inflammable matters. Hepatic gas, from whatever ſubſtance it is produced, gives it, as ſoon as it touches it, a blue or violet colour inclining to black, and diminiſhes its ductility. It is a matter of obſervation, that animal hepatic vapours, ſuch as thoſe of privies, of putrrefied urine, warm eggs, produce the ſame effects upon it. The reciprocal action of theſe two bodies has not yet been examined, nor the kind of combination formed. Sulphur combines very well with it. For this purpoſe ſilver plates are ſtratified with flowers of ſulphur, and quickly fuſed; a maſs of a violet black reſults, much more fuſible than the ſilver, brittle, and diſpoſed in needles; in ſhort, a true artificial ore. This combination is eaſily decompoſed by the action of fire, on account of the volatility of the ſulphur and the fixity of the ſilver: the ſulphur is conſumed and diſſipated, and the ſilver remains pure. Liver of ſulphur diſſolves this metal in the dry way; by fuſing one part of ſilver with three of liver of ſulphur, the metal diſappears, and may be diſſolved in water along with the liver. If an acid is poured into this ſolution, a ſulphureous black precipitate of ſilver is obtained. Silver-leaf, put into liquid liver of ſulphur, very ſoon aſſumes a black colour; and it ſeems that the ſulphur leaves the alkali to unite with and mineraliſe the ſilver, as we have already ſeen with regard to mercury.

Silver unites with arſenic, which renders it brittle. The action of the arſenical acid upon it is not known. It difficultly combines with cobalt. It alloys very well with biſmuth, with which it forms a brittle mixed metal, whoſe ſpecific gravity is greater than that of the two metals taken ſeparately.

According to M. Cronſtedt, it does not unite with nickel: theſe metals, fuſed together, lie at the ſide of one another, as if their ſpecific gravity was perfectly identical.

It fuſes with regulus of antimony, and forms a very brittle alloy. It ſeems capable of decompoſing the antimony, and of uniting with its ſulphur, with which it has more affinity than with the regulus. Zinc eaſily combines with ſilver by fuſion; and a very brittle alloy, granulated at its ſurface, reſults from this combination.

In mercury it diſſolves completely, even in the cold: ſilver-leaf is mixed with it; and an amalgam inſtantly reſults, varying in conſiſtence, according to the reſpective quantity of the two ſubſtances employed.

This amalgam is ſuſceptible of a regular form by fuſion and ſlow cooling: it yields three-ſided priſmatic cryſtals, terminated by ſimilar pyramids. The mercury aſſumes a ſort of fixity in this combination; for, in order to ſeparate it from the ſilver, a more conſiderable degree of heat is required than that which it requires for volatiliſation *per ſe*. Silver can decompoſe corroſive ſublimate, both by the dry and moiſt way. It perfectly unites with tin, by which it is totally deprived of all its ductility. It alloys readily with lead, which renders t very fuſible, and deprives it of its elaſticity and ſonorous quality. It alloys with iron; which, although little examined, yet might perhaps become of great uſe in the arts.

Silver is a metal which is of ſingular utility on account of its ductility and its indeſtructibility by the fire and air. ts brilliancy recommends it as a beautiful ornament. It s applied upon the ſurface of different bodies, and alſo upon copper. Stuffs are wrought with it, and have their beauty heightened. But its moſt important uſe is to form, by its hardneſs and ductility, veſſels of all forms. Table-ſilver is generally alloyed with a twenty-fourth of copper, which gives it more hardneſs and adherence; expoſing the health to no inconvenience, becauſe the twenty-three parts of ſilver cover and entirely deſtroy the deleterious properties of the copper.

Laſtly, Silver is employed as the price of all merchandiſes, and is formed into money; but in this caſe t is alloyed with a twelfth of copper, and is called *ſilver of eleven marks*.

LECTURE XLI.

Species 14. GOLD.

GOLD, or *Sol* of the chemiſts, is the moſt perfect and moſt unchangeable metal known: it is of a brilliant yellow colour. It is the heavieſt body in nature; it loſes only between a nineteenth and a twentieth part of its weight in water. Its hardneſs is not very conſiderable, as alſo its elaſticity. Its aſtoniſhing ductility, ſo conſpicuous in the art of wire-drawing and of gold-beating, is ſo great, that one ounce of it is able to gild a ſilver thread 444 leagues long; and it may be converted into leaves which the wind may carry away. A grain of gold, according to Lewis's calculation, can be made to cover a ſpace of more than 400 ſquare inches. It is the moſt tenacious of all the metals; a weight of 500 pounds being ſupported by a thread of it only one-tenth of an inch in diameter, before breaking. It ſtiffens eaſily under the hammer; but nealing reſtores all its ductility.

The colour of gold is ſuſceptible of a great number of varieties: there is ſome of it more or leſs yellow or pale; ſome of it which inclines almoſt to white: it is ſuppoſed that theſe differences depend upon ſome foreign ſubſtance. Gold has neither ſmell nor taſte: it is ſuſceptible of cryſtallization, by cooling, into ſhort quadrangular pyramids. In this form it was obtained by Meſſrs Tillet and Mongez.

Gold is found always pure in nature. It is ſometimes found in ſmall iſolated or continued maſſes, and ſcattered in quartz: at other times, it is in ſmall pieces amongſt the ſand at the bottom of waters: laſtly, it is got from ſeveral ores, into whoſe compoſition it enters; ſuch as the galenas, the blendes, red ores of ſilver, and native ſilver. It is united almoſt always with a certain quantity of ſilver, and forms a kind of natural alloy.

Mineralogiſts diſtinguiſh ſeveral varieties of native gold, in plates, in grains, in octaëdral cryſtals, in priſms with four ſtriated ſides, in threads, and in irregular maſſes. M. Sage thinks, that priſmatic native gold is combined with a certain quantity of mercury, which renders it brittle.

The eſſaying of a gold-ore ſhould differ according to its nature: if it is native gold, pulveriſation and waſhing ſuffice;

uffice; if gold is alloyed with other metals, the ore muſt be roaſted, fuſed, and cupelled with lead, and parted.

The way in which gold is extracted from its ores is very eaſily conceived, from what has been already ſaid upon metallurgy. Native gold requires only ſeparation from its matrix. For this purpoſe it is taken to the ſtamping-mill: it is waſhed, to carry away the matrix, which has been reduced into powder; it is brayed in a veſſel full of water, with ten or twelve parts of mercury; the water is made to run off, and carries away every thing which is earthy. When this amalgam, which is formed in the operation, is freed of all the earth, and it appears very pure, it is ſqueezed through ſhamoy leather; a good part of the mercury paſſes through, and the gold remains united with a certain quantity of it. The amalgam of gold is heated, and the mercury ſeparated by diſtillation; then the pure gold is fuſed which reſults from this operation, and run into bars or ingots. With regard to the gold which is found combined in the ores of other metals, as in thoſe of lead and copper, it is extracted by cupellation and parting from the former; and the lead, which runs off during the liquation of the copper, carries away the ſilver, and gold; then it is cupelled, and the ſilver is ſeparated by parting *.

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* Beſides parting by quartation, there are two other kinds of parting practiſed in trade, the concentrated parting and the dry parting. The concentrated parting conſiſts in expoſing the metal to very ſtrong acid fumes, by cementation with a mixture of proper materials. The mixture is a compound of calcined vitriol and nitre well rubbed together in powder. Some of this is put into a cementing pot, and the piece of gold to be purged, beat into the ſize of a common coin, is laid over it, and layers of the metal and compoſition, ſtratified alternately, till the veſſel be full. By raiſing the fire, the vitriol acts upon the nitre, and ſets the acid free; and thoſe acid vapours inſtantly penetrate the metallic maſs, and diſſolve the ſilver. It is, however, obſerved, that they do not thoroughly pervade the whole, deſtroying only the ſilver which lies near the ſurface; ſo that this method is only employed when nothing but a ſuperficial purity is wanted.

Gold expoſed to the fire turns red long before fuſion. When it is very red, it appears brilliant and of a clear green colour, reſembling the beryl. It does not fuſe till it be of a white red: cooled ſlowly, it cryſtalliſes. It ſuffers no alteration whatever by the ſtrength of the fire, or length of expoſure to it, ſince Kunckel and Boyle kept it ſeveral months in a glaſs-houſe fire without appearance of alteration. However, this kind of unalterability is only relative to the fires which are made by means of combuſtible ſubſtances; ſince there appears no doubt, that a much more active heat, as the focus of burning lenſes, is capable of depriving gold of its metallic properties. Homberg obſerved, that upon expoſing gold to the focus of Tſchirnhauſen's lens, it ſmoked, was volatiliſed, and even vitrefied. M. Macquer ſaw gold expoſed to the focus of M. de Trudaine's lens fuſed, which emitted a fume that gilded ſilver, and was gold only volatiliſed: the globule of gold, when fuſed, was

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In dry parting, the alloy of gold and ſilver is granulated, by making the melted metal run from a crucible into water, which is kept in rotatory motion, ſo as to divide the metal into grains. Three-fourths of this granulated metal is rubbed in flowers of ſulphur, which adheres to the ſurface while wet; and this is put into a crucible over the fire, and remelted with a gradual heat, that the ſulphur may penetrate the ſilver without flying off; for the proceſs proceeds upon the principle of ſulphur uniting with ſilver, while it has no attraction for gold. After the heat has brought the ſulphurated ſilver into thin fuſion, the gold-holding granulated ſilver is added by degrees, which, as it melts, diffuſes all over the maſs, and collects the particles of gold which were interſperſed in the ſulphurated ſilver, and precipitates with it to the bottom of the crucible. For although ſilver has greater affinity to ſulphur, and combines intimately with it by a kind of cementation, it does not eaſily mix with ſulphurated ſilver which is already in fuſion. By this operation, the proportion of ſilver to gold is much diminiſhed, and the purification may afterwards be completed in the ordinary way. This proceſs is found to be ſo uſeful in great works, that at Rammelſberg, where 100 pounds of ore contain about 40 pounds of tin, and the tin 110 grains of ſilver, and the ſilver one-third of a grain of gold, the tin is wrought off, and this minute quantity of gold ſeparated with profit.

was agitated with a rapid motion, was covered with a dull pellicle, wrinkled, and apparently calciform: that at laſt a violet vitrification was formed in its middle. This vitrefication gradually increaſed, and gave riſe to a ſort of cap of a greater inflection than that of the maſs of gold which was encaſed in this maſs, as the tranſparent cornea is upon the ſclerotic coat. This glaſs increaſes as the gold diminiſhes. Upon the ſupport is always found ſomewhat of a purple ſtain, which ſeemed to be owing to a portion of glaſs which had been abſorbed, M. Macquer has not yet had opportunity to vitrefy a given quantity of gold. This celebrated chemiſt obſerved, that it was neceſſary to reduce this violet glaſs with combuſtible matters, in order to be aſſured of its containing gold, before concluding that it was the calx of this perfect metal. However it be, it is our opinion, that it is a true vitrefied calx of gold; and with the firmer foundation, that in ſeveral proceſſes upon this metal, which we ſhall preſently deſcribe, it aſſumes conſtantly the purple colour; and that ſeveral of its preparations are employed to communicate this colour to enamels and porcelain. Like the other metals, then, gold is calcinable; only, like ſilver, it requires to unite with the air a more intenſe heat, and a longer time, than all the metallic ſubſtances. Theſe circumſtances are, without doubt, relative to its denſity.

Gold is unchangeable by the air; its ſurface is only tarniſhed by foreign ſubſtances which float inceſſantly in it; nor is it altered by water in any degree. From the inveſtigations, however, of M. le Compte de la Garaye, it appears to be capable of dividing it, nearly in the ſame way as it does iron.

Gold, in its metallic ſtate, does not combine with the earths and ſaline earthy ſubſtances; but its calx can enter into the compoſition of glaſs, to which it gives a violet or purple colour.

The moſt concentrated vitriolic acid, aided even by heat, has no degree of power over this perfect metal.

The nitrous acid may take up ſome atoms of it: only, perhaps, in a mechanical way, rather than by a true combination. M. Brandt is one of the firſt chemiſts who has announced its ſolubility in this acid: Meſſrs Scheffer and Bergman have confirmed it. But it is to be obſerved, that, from the experiments of the whole body of chemiſts of the Academy, this acid takes up the gold only under certain circumſtances, which theſe gentlemen have not yet mentioned. M. Deyeaux, member of the College of Pharmacy, has diſcovered, that the nitrous acid diſſolves gold only when it is ſmoking and charged with nitrous gas. The acid in this ſtate is, in his opinion, not pure: he calls it acid charged with gas, and compares it to a kind of aqua regia.

The marine acid *per ſe*, and in a pure ſtate, does not ſenſibly act upon gold. Meſſrs Scheele and Bergman aſſures us, that this acid, dephlogiſticated or diſtilled from the black calx of mangaueſe, which, according to theſe chemiſts, ſeizes upon this acid's phlogiſton, diſſolves gold like aqua regia, and with this metal forms the ſame ſalt which is uſually produced by employing this ſame mixed acid. Theſe experiments have not yet been repeated in an accurate manner; and the reſult of theſe experiments has not yet received the ſanction of chemiſts, which ought to eſtabliſh the reliance upon them which they deſerve *.

Aqua regia is ſtill looked upon as the true ſolvent of gold. We ſhall not repeat what we have elſewhere ſaid upon the nature, properties, and differences of this mixed acid, according to the quantity of the two acids combined for its formation. Here we ſhall take notice only of its action upon gold. As ſoon as aqua regia comes into contact with this metal, it attacks it, raiſing an effervescence, which is greater or leſs, according to its concentration, the heat, and the diviſion of the gold. An acceleration of the proceſs may be produced by heat, or at leaſt the heat may favour the commencement of their action. The air bubbles riſe without interruption, till a portion of the metal is diſſolved. This action gradually ſtops till agitation or heat be employed. The gas diſengaged in this ſolution has not been examined. Aqua regia, charged with all the gold which it can take up, is of a more or leſs deep yellow: its cauſticity is conſiderable: it tinges animal matters of a deep purple colour, and corrodes them. When it is cautiouſly evaporated, it gives cryſtals of a fine golden colour, which reſemble topazes, and appear to be truncated octagons, and ſometimes four-ſided priſms. It is difficult to obtain this cryſtalliſation. M. Monnet is of opinion, that it ariſes only from the neutral ſalt formed in aqua regia; and he ſays farther, that in order to obtain it, it is neceſſary to employ an aqua regia made with nitrous acid and ſal ammoniac or marine ſalt: Hence this mixed acid contains either cubic nitre, or nitrous ammoniac. The one or the other of theſe ſalts, according to this chemiſt, is the cauſe of the cryſtalliſation of the gold. It is not, however, entirely demonſtrated, that a ſolution of gold in aqua regia, which conſiſts of uncombined marine and nitrous acids, is incapable of giving cryſtals; ſince, as M. Bergman imagines, this ſalt of gold contains marine acid only which may be extracted by diſtillation. If the cryſtals of gold are heated, they fuſe and take a red colour: this ſalt ſtrongly attracts the air's humidity. If a ſolution of gold is diſtilled in a retort, a fine red liquor is obtained, which has brought over with it a little gold, and ſeems to be marine acid. The alchemiſts, who were very laborious upon gold, gave the name of *red lion* to this liquor. Some cryſtals of a reddiſh yellow are alſo ſublimed. The greateſt part of this metal remains at the bottom of the retort, and requires fuſion only in order to be very pure, and to enjoy all its properties.

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* Our learned author ſeems here to entertain great doubt of the ſolubility of this perfect metal in the acid in this ſtate. It is a fact of which he might have ſatisfied himſelf with the greateſt facility. There is no metal whatever which marine acid, thus dephlogiſticated, will not diſſolve; and it very readily acts upon gold when conveniently expoſed to its action.

The ſolution of gold may be decompoſed by a great number of ſubſtances. Lime and magneſia precipitate its gold in form of a yellow powder. The fixed alkalis preſent the ſame phenomenon: but it muſt be obſerved, that the precipitate forms but very ſlowly, and that the ſolution aſſumes a reddiſh colour, if more of the alkali was put in than was ſufficient; becauſe the exceſs of this ſalt rediſſolves the precipitate. This precipitate may be reduced by heat and in cloſe veſſels: it is a calx which eaſily parts with the air, with which it is combined. However, it is ſuſceptible of fuſion with the vitreſcent ſubſtances, and of giving them a purple colour; as for enamels and porcelain, a precipitate of gold is employed, which is formed by the admixture of a ſolution of gold and of the liquor ſilicum.

Gold, precipitated by the fixed alkalis, preſents a property ſtill very different from thoſe of gold in its metallic ſtate, which is its ſolubility in the vitriolic, nitrous, and marine acids, when uncombined. All theſe acids, heated upon a yellow ſolution of gold, eaſily diſſolve it; but they cannot take up enough of it to give cryſtals. When theſe ſolutions are evaporated, the gold very readily ſubſides, which it does too by ſimple repoſe. M. Monnet has taken notice of a fact which ſhould not be forgotten, in the precipitation of a ſolution of gold by means of the gall-nut*; it is, that this pre-

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* As we have made mention only of the precipitation of iron by the gall-nut, we think it proper to give here a brief account of the phenomena which this aſtringent ſubſtance preſents with the moſt part of the metallic ſolutions.

The ſolution of cobalt is precipitated of a clear blue by it; that of zinc, of an aſh-coloured green; that of copper, of a green, which becomes grey and reddiſh; that of ſilver, at firſt in reddiſh ſtriæ, ſoon aſſuming the colour of burnt coffee; that of gold, purple; that of precipitate, which is reddiſh, diſſolves very well in the nitrous acid, which by this means acquires a blue colour.

The volatile alkali throws down from the ſolution of gold a much more copious precipitate. This precipitate, which is of a brown yellow, and ſometimes of an orange, has the peculiar property of detonating with a conſiderable noiſe when it is ſlowly heated: it has been called *aurum fulminans*. The volatile alkali is abſolutely neceſſary for its formation: for this purpoſe, it may be produced either by precipitating with the fixed alkali a ſolution of gold made in aqua regia, which is compoſed of ſal ammoniac; or, what is better, by precipitating with the volatile alkali a ſolution of gold made in aqua regia, conſiſting of the nitrous and marine acids in their pure ſtate. A fourth more of fulminating gold is always obtained than the quantity of gold which has been diſſolved in the aqua regia. There are ſeveral precautions deſerving attention, relatively to the terrible effects of aurum fulminans. It ought to be carefully dried in the open air, without expoſing it to the heat of a fire. As a ſtrong heat is not requiſite for its fulmination, and as friction alone ſuffices for the production of the exploſion, the veſſels in which it is kept ſhould be ſtopped only with cork. Unhappy experience has appriſed us of the dangers incident from the uſe of cryſtal ſtoppers, by the friction which they produce upon the neck of the veſſels when any portion of

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of platina, black. Theſe are the facts obſerved and deſcribed by M. Monnet; who has obſerved beſides, that theſe precipitates are ſoluble in the acids, and that the alkalis unite to their ſolutions without any ſign of precipitation.

Meſſrs the academicians of Dijon have added to theſe facts the following obſervations: The ſolution of arſenic is not altered by the gall-nut; that of biſmuth gives a greeniſh precipitate; that of nickel, a white; that of antimony, a blueiſh grey; that of lead, a ſlaty-like depoſition, whoſe ſurface is covered with pellicles mixed of green and red; laſtly, that of tin becomes of a dirty grey by the mixture of the gall-nut; and it gives a precipitate which is copious, and as if mucilaginous.

of the powder ſticks there. A terrible accident happened with M. Baumé; an account of which is found in his Experimental and Rational Chemiſtry, vol. iii. p. 79.

Chemiſts have entertained different notions upon the cauſe of the detonation. M. Baumé thought, that in the detonation a nitrous ſulphur was formed, to which he aſcribed the fulminating property. But M. Bergman has proved the inadmiſſibility of this theory, having diſcovered a method of making fulminating gold without nitrous acid, by diſſolving a precipitate of gold in vitriolic acid, and precipitating it afreſh by the volatile alkali. Nor upon the nitrous ammoniac has the fulmination any greater dependence; for after this compound has been waſhed with plenty of water, to carry off all the ſalt, if it contained any, it does not loſe its fulminating property. Upon a ſtrict examination of what paſſes in the detonation, it is obſerved to inflame the moment it ſhines. If it is heated upon a gentle fire of hot cinders, brilliant ſparks fly off before exploſion, reſembling the electric flaſh: it detonates when it is expoſed to the ſpark produced by the electric bottle; a ſimple ſpark does not kindle it without commotion: laſtly, after fulmination, a part of the gold is left in the ſtate of a purple calx, and another part in its metallic ſtate. Hence it appears, that the fulmination depends upon a combuſtible matter contained in it; and as the alkaline gas, to which we have aſcribed a kind of combuſtibility, is required for the production of fulminating gold, is it not very probable that the exploſion of this ſubſtance depends upon this alkaline gas? This theory is the more ſupported, as M. Berthollet, my colleague, obtained ſome alkaline gas by heating ſome fulminating gold in copper tubes, whoſe extremity was immerſed, by means of a ſyphon, into a pneumato-chemical apparatus with mercury. After this bold experiment, the gold was no longer fulminating, and it was reduced into a calx. M. Bergman made an experiment of the ſame kind, which proves abſolutely the ſame thing. He expoſed gold to a heat which was incapable of making it fulminate; and he deprived it of this property, no doubt, by the gradual volatiliſation of the alkaline gas. However, it muſt be obſerved, that this gas is truly, and even very intimately, combined with the gold; ſince boiling water, M. Bergman ſays, carries none of it away; and the vitriolic acid and fixed alkali are unable to deprive it of its fulminating virtue. However, M. Baumé, who cites this chemiſt's experiments, whoſe work he ſeems to know, ſays, that vitriolic acid and fixed alkali decompoſe fulminating gold. Fulminating gold ſeems ſuſceptible of loſing its property by admixture with ſulphur. Oil very ſoon deprives it of it, as Meſſ. Rouelle and d'Arcet have diſcovered. Æther, and ſeveral other inflammable bodies, whoſe properties ſhall be mentioned in the hiſtory of the vegetable kingdom, are, according to M. Bergman, proper to deprive fulminating gold of this property. A ſingular property of fulminating gold, and which announces its ſtrength, is, that when made to fulminate upon a plate of metal, ſuch as lead, tin, and even ſilver, a mark or hole is made in the plate: farther, it does not ſeem ſuſceptible of kindling in cloſe veſſels, ſince M. Lewis found, that when it was ſhut up in an iron ball, it produced no exploſion. Fulminating gold is very capable of ſolution in the acids: when it is ſeparated from theſe ſalts by the fixed alkali, it is no longer fulminating; and if the volatile alkali is employed, it is found to be in its former ſtate.

The ſolution of gold is precipitated by liver of ſulphur. Whilſt the fixed alkali unites with the aqua regia, the ſulphur which is precipitated combines with the gold; but this combination is not durable: heat alone is required to volatiliſe the ſulphur, and to obtain the perfect metal in its ſtate of purity. We may obſerve here, that gold, precipitated from aqua regia by any intermedium whatever, is perfectly pure; and that it is even more pure than parted gold; becauſe it is ſeparated from the ſilver which it might have contained by the precipitation of this metal with the marine acid, forming luna cornea, which takes place even during the ſolution of the gold, as has been mentioned more fully above.

Gold is not the metal which has the ſtrongeſt affinity with aqua regia; almoſt all the metallic ſubſtances have the power of ſeparating it from its ſolvent. Biſmuth, zinc, and mercury, precipitate it. A plate of tin put into its ſolution ſeparates this metal in the form of a deep violet powder, called *purple precipitate of Caſſius*. This precipitate is employed in painting enamels and porcelain, and is prepared by diluting a ſolution of tin in aqua regia with a great quantity of diſtilled water, and pouring into it ſome drops of a ſolution of gold. When the ſolutions are pretty copious in metal, a precipitate is preſently formed of a crimſon red, which becomes purple in a few days: the liquor is filtrated, and the precipitate waſhed and dried. This ſubſtance is a calx of tin and of gold: its preparation is one of the moſt ſingular operations in chemiſtry, on account of the variety and inconſtancy of the phenomena which it exhibits. Sometimes it gives a precipitate of a fine red; ſometimes its colour is a deep violet; and, what is more aſtoniſhing, it very often happens that the mixture of theſe two ſolutions occaſions no precipitate. M. Macquer, who has given a full account of theſe varieties, obſerves, that they depend almoſt always upon the ſtate of the ſolution of tin employed. If this ſolution has been made too rapidly, the metal is too much calcined, and it contains too little of it, in order that the aqua regia of the ſolution of gold may act upon it; for it is the action of this laſt upon the tin to which he aſcribes the formation of the purple precipitate of Caſſius. In order to ſucceed, then, in this operation, a ſolution, made very ſlowly, ſhould only be employed, in ſuch a ſtate as to contain the greateſt poſſible quantity of tin without the metal being entirely calined in it. Hence he adviſes this method of preparing the purple precipitate. Let ſmall pieces of tin be diſſolved in aqua regia which has been made with two parts of ſpirit of nitre and one of ſpirit of ſalt, weakened with its equal weight of diſtilled water: on the other hand, let very pure gold be diſſolved by means of heat in an aqua regia compoſed of three parts of ſpirit of nitre and one part of ſpirit of ſalt: let the ſolution of tin be diluted with a hundred parts of diſtilled water, and let it be divided into two portions: to one of the two let a new quantity of water be added: let them both be tried with a drop of ſolution of gold; then, by obſervation, diſtinguiſh the fineſt red, in order to treat them both in the ſame manner; then let the ſolution of gold be poured in till no more precipitate falls.

Lead, iron, copper, and ſilver, alſo have the property of ſeparating gold from its ſolution. Lead and ſilver precipitate it in a dirty deep purple; copper and iron ſeparate it in its metallic brilliancy; the nitrous ſolution of ſilver and that of martial vitriol, likewiſe occaſion a red or brown precipitate in the ſolution of gold *.

The

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* Gold may alſo be ſeparated from aqua regia by the addition of certain inflammable ſubſtances, which furniſh phlogiſton to the gold-earth, and ſo revive it in a metallic ſtate. Thus, when a quantity of any eſſential oil, or, ſtill better, of vitriolic æther, is poured into a ſolution of gold in aqua regia, the gold gradually forſakes the acid menſtruum to unite with the oil or the æther. This ſeparation will even take place when the æther or eſſential oil is merely poured upon the ſurface of the ſolution, and left at reſt; though the proceſs will ſucceed better, and is ſooner finiſhed, when the two fluids are mixed together by agitation. The æther abſorbs the whole gold, and keeps it afterwards perfectly ſuſpended; and as it has no effect upon any other metal, this ſeems the beſt teſt of the preſence of gold. It is alſo evident that the gold will be obtained in a ſtate of moſt perfect purity, from the attraction of the æther being confined to this metal alone. The eſſential oils acquire a deep yellow colour when allowed to remain ſome time upon the ſolution; but do not long retain the gold ſuſpended, as it ſoon ſeparates,

The neutral ſalts have no remarkable action upon gold; only it is obſerved, that borax fuſed with it alters its colour, and makes it remarkably pale; whereas nitre and marine ſalt heighten it. The ſolution of borax poured into one of gold, occaſions a precipitate of ſedative ſalt charged with the metal.

Sulphur does not unite with gold; and is therefore uſed with advantage in the ſeparation of the metals which are united with gold, but particularly ſilver. This alloy is fuſed in a crucible: when it is fuſed, flowers of ſulphur are projected upon its ſurface: this ſubſtance fuſes and combines with the ſilver, ſwimming in the form of black ſcoriæ above the gold. It muſt be obſerved, that theſe two metals are never completely ſeparated by this operation, which is named *dry parting*, and is employed only to a maſs of ſilver which contains too little gold to be capable of indemnifying the expence ariſing from the uſe of aquafortis.

Liver of ſulphur diſſolves gold completely. It is Stahl's opinion, that by this proceſs Moſes diſſolved the golden calf which the Iſraelites worſhipped. The ſolution is formed by rapidly fuſing a mixture of equal parts of ſulphur and fixed alkali with an eighth of the whole weight of gold-leaf. This matter is run upon a po-

rates, and adheres to the ſides of the veſſel in the form of metallic films: yet after this ſeparation of the gold, the eſſential oils ſtill exhibit a bright yellow colour, which many through miſtake attribute to the particles of gold in the oil, though in reality the tinge ariſes from the action of the acids; as ſtrong acids do at all times produce this change upon the colour of eſſential oils. From this error many have been led to believe themſelves in poſſeſſion of potable gold, by diſſolving thoſe coloured oils in highly rectified ſpirit of wine; and either from fraud, ignorance, or deluſion, endeavoured to impoſe upon the credulity of mankind; for the alchemiſts boaſted of certain mild ſolutions of gold as invaluable ſecrets: they proclaimed them to be efficacious remedies in every diſorder; to cure every human evil without pain; and even to be capable of prolonging life itſelf. How fallacious thoſe hopes were, and how imprudent it is to truſt in the promiſes of pretenders to myſterious diſcoveries, is now ſufficiently known from the detection of many impoſtures of this kind.

poryphyry: it is pounded; ſome diſtilled water is poured upon it: it forms a ſolution of a yellowiſh green, which contains a golden liver of ſulphur. The metal may be precipitated by means of the acids, and ſeparated from the ſulphur, which is depoſited along with it, by the application of heat in open veſſels.

Gold combines with the moſt part of the metallic ſubſtances, and exhibits ſeveral important phenomena in its combinations.

It unites with arſenic. This ſemimetal renders it brittle, and gives it a very pale colour. There is great difficulty in ſeparating by heat the laſt portions of arſenic from this alloy; the gold ſeems to give it fixity: its alloy with cobalt is not known. It unites with biſmuth, which renders it brittle. The ſame is the caſe with nickel and regulus of antimony. As all theſe metals are very calcinable, and the moſt part fuſible, it is very eaſy to ſeparate them from the gold by the action of fire combined with that of the air. Crude antimony was boaſted of by the alchemiſts for the purification of gold. When it is fuſed with this metal, alloyed with any foreign metallic ſubſtances, as copper, iron, or ſilver, the ſulphur unites with theſe ſubſtances, and ſeparates them from the gold, which is found at the bottom of the veſſel. This gold is alloyed with regulus of antimony: it is purified by heating it with a white-red heat. The regulus of antimony is volatiliſed; the laſt portions require a very violent fire: and it is obſerved, that this ſemimetal carries along with it ſome portions of gold in its volatiliſation. This proceſs, ſo celebrated among the alchemiſts has, therefore, no advantage over that in which ſulphur only is employed.

Gold very eaſily alloys with zinc: a mixt metal reſults, whoſe brittleneſs and whiteneſs increaſes according to the greater proportion of this ſemimetal. This alloy, made with equal parts, is of a very fine grain; and it takes ſo fine a poliſh, that it was recommended by Hellot to make mirrors of teleſcopes, which are not ſubject to tarniſh. When the zinc is ſeparated from the gold by calcination, the flowers of this ſemimetal are reddiſh, and carry along with it a little gold, as Stahl has announced.

Gold has more affinity with mercury than with the other metallic ſubſtances, and is capable of decompoſing their amalgams. It unites with it in all proportions, and forms an amalgam, whoſe colour and ſolidity augment according to the greater or leſs quantity of gold employed. This amalgam liquefies by heat, and cryſtalliſes by cooling, as all the compounds of this ſemimetal do. What regular form it aſſumes is not properly known. M. Sage ſays, that its cryſtals reſemble ſilver *en plume*, and with a microſcope ſeem to be quadrangular priſms: he ſays alſo that the mercury here acquires fixity. This amalgam is employed to gild with. Although gold be incapable of calcination by the heat of our furnaces, and by the contact of air, it becomes calcinable, however, when heated conjointly with mercury. Some mercury being put along with a forty-eighth of its weight of gold into a matraſs with a flat bottom, whoſe neck has been drawn out by means of an enameller's lamp, in order to leave but a very ſmall opening; and the mixture being heated in a ſand bath, as is done in the preparation of the calx of mercury called *precipitate per ſe;* theſe two metallic ſubſtances calcine at one time: they are changed into a deep red powder; and this double calx is obtained even much more readily than that of mercury heated alone, according to M. Baumé. Here then is a metal which, though very difficult to calcine alone, haſtens and facilitates, however, the calcination of another metallic ſubſtance, which *per ſe* is very incapable of ſuch an alteration.

Gold alloys very well with tin and lead. Theſe two metals deprive it of all ductility. Its alloy with iron is very hard, and may be uſed to make ſharp inſtruments, much ſuperior to thoſe which are made with pure ſteel.

This mixt metal is grey and attractable by the magnet. M. Lewis propoſes the uſe of gold in ſoldering properly and ſolidly ſmall pieces of ſteel.

Gold combines very well with copper, which gives it a red colour and a great ſtiffneſs, and renders it more fuſible. This alloy, in different proportions, is uſed for coin, and in the making of veſſels and trinkets. Laſtly, gold alloys with ſilver, which deprives it of its colour, and renders it very pale. This alloy, however, is not made without a certain difficulty, on account of the difference of weight between theſe two ſubſtances, juſt as Homberg has obſerved; who has ſeen them ſeparate during fuſion. The alloy of gold and ſilver forms the green gold of the jewellers.

As gold is of very extenſive uſe, as is the caſe with ſilver, the price of all the productions of nature and of art, it is of very great importance to fix the degree of purity of this precious metal, to prevent the exceſs to which avarice might proceed, and to eſtabliſh the value of all the maſſes or pieces of gold vended in commerce. By juſt and ſtrict laws, the quantity of alloy has been preſcribed, which is neceſſary to communicate hardneſs and ſtiffneſs to the gold deſtined for making utenſils, in which theſe properties are requiſite. Chemiſtry has furniſhed means of aſcertaining the quantity of imperfect metals combined with gold. The operation is called *eſſaying the title of gold.* Twenty-four grains of the gold which we want to eſſay, are cupelled with forty-eight grains of ſilver and four of pure lead. This laſt, in its vitrefication, carries off the imperfect metals: the gold remains in combination with the ſilver after cupellation. Theſe two metals are ſeparated by an operation called *parting*. Parting an alloy of ſilver and gold, is ſeparating the two metals by means of a ſolvent, which acts upon the ſilver without touching the gold. Aquafortis is generally uſed. The ſilver is added to the gold, becauſe experience has taught us, that it is neceſſary that the gold contain at leaſt double its weight of ſilver, in order that the nitrous acid may diſſolve the ſilver entirely. As three parts of ſilver are often added to gold, this operation is called *inquart* or *quartation*, becauſe the gold makes in fact the fourth of the alloy.

After having flattened the button with the hammer, and taken care to heat and agitate it frequently, in order to prevent it from cracking, and the ſeparation of any portions of it by the ſtiffening of the piece; it is rolled upon a feather, and a kind of cornet is formed; it is put into a ſmall matraſs, and above five or ſix gros of precipitated aquafortis, diluted with half its weight of water, are poured in. The veſſel is gently heated till the effervefcence be fairly commenced; then the ſilver diſſolves, and the cornet aſſumes a brown colour. When the action of the acid is over, the acid is poured off and replaced by a freſh portion, which is made to boil above the metal till all the ſilver be diſſolved. The acid is poured off and the cornet waſhed, which has become very thin and full of holes; it is put with ſome water into a crucible, the water is decanted, the crucible made red hot, and the gold then enjoys all its properties. Its weight is found, by which we judge of the alloy which it contained, or of its title. In order to aſcertain exactly the quantity of imperfect metals which it contained, let us ſuppoſe any maſs of gold to be compoſed of 24 parts, called *carats*; and for greater preciſion's ſake, let each carat be ſubdivided into 32 parts, each called $\frac{1}{32}$ of a carat. If the gold which has been eſſayed has loſt one grain upon the 24, it is gold of 23 carats; if it has loſt a grain and a half, gold of $22\frac{16}{32}$ carats; and ſo forth. The weight employed in the eſſay of gold is generally 24 grains, the weight of a mark; it is divided into 24 carats, which are ſubdivided into 32 parts. Half a mark is alſo made uſe of, which weighs 12 grains, but divided into 24 carats, and each carat into 32 thirty-twos[*].

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[*] A tolerable eſtimate may be formed of the purity of gold from

There are two important obſervations to be made upon the operation of parting.

1. Some chemiſts have ſuppoſed that the nitrous acid diſſolved a little gold along with the ſilver. M. Baumé,

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inſpecting the colour of the maſs by perſons who are accuſtomed to judge in this way. The accuracy of their judgment is alſo aſſiſted by a ſet of proof-needles, which ſerve as ſtandards of compariſon to point out the quantity of baſe metal uſed in alloy. Theſe needles are compoſed of a certain proportion of the metals ſuppoſed to be in the mixture, forming a regular gradation from the pureſt gold, or gold of 24 carats fine, down to 12 carats or one half, though ſome extend the ſeries ſtill lower. Dealers in gold are commonly provided with four or five ſet of touch-needles; the firſt ſet, conſiſts of pure gold alloyed with ſilver alone; the ſecond, of gold, alloyed with a mixture of two parts of ſilver and one part of copper; the third, equal parts of ſilver and copper; and the fifth, of pure copper, which is uſed without any alloy of ſilver. When a piece of gold is to be valued from inſpection, a ſtroke is to be drawn upon a black ſtone called *a touch-ſtone*, and another ſtroke parallel to this by the needles which approach neareſt to the colour of the maſs. This touchſtone muſt poſſeſs certain properties, in order to anſwer the purpoſe well. It muſt be of a deep colour, nearly black, to ſhow the colour of the metal diſtinctly. It muſt not be too ſmooth, otherwiſe ſoft gold will not eaſily leave a mark upon it; nor too rough, elſe the mark proves imperfect. When too hard, cleaning the ſtone from the ſtrokes poliſhes the ſurface too much; and when too ſoft, it is liable to be ſcratched in cleaning. It muſt alſo be inſoluble in acids; otherwiſe the aquafortis, poured upon its ſurface to try the preſence of baſe metals, will corrode the ſtone itſelf. The ſtrokes drawn are in general a quarter of an inch long, and one eighth of an inch broad; and when the firſt needle does not perfectly reſemble the original maſs, we make repeated trials with others, until the reſemblance be more complete. Then we pour ſome aquafortis upon the ſtone, to ſee whether the metal be only an imitation of the colour of gold. If it contain no gold, the whole ſtroke is completely diſſolved away, and is always eroded in proportion to the quantity of inferior metal with which the gold is debaſed. In this way the touchſtone is employed as a teſt of the fineneſs of gold; though, it muſt be confeſſed, that it is far from being accurate, unleſs the nature of the alloying metal be known to the inſpector.

But in China, where no alloy is uſed except pure ſilver, the leaſt admixture of copper creating ſuſpicion of fraud, and where eſſays are not commonly permitted in trade, the merchants are ſaid to be very accurate in their judgment, and to eſtimate the fineneſs of gold within pages 117, 118. of the third volume of his Chemiſtry, has obſerved, that parted ſilver retained a conſiderable quantity of gold. From two pounds of grained ſilver which this chemiſt made uſe of, to make lapis infernalis, he ſays he generally ſeparated more than a half gros of gold in a black powder. However, by performing the parting with an acid, which was not too concentrated, and urging the ſolution not too far, the gold remains pure and untouched, and the ſilver contains none of it. The Profeſſors of Chemiſtry of the Academy having been deſired by Adminiſtration to examine, if, in the proceſs employed for parting, the nitrous acid diſſolved the gold, they made a great number of experiments; from which they concluded, "that, in the parting practiſed according to the regulations and received uſe, a loſs of gold never can take place; and that this operation ought to be looked upon as carried to perfection." This deciſion, extracted from the report publiſhed by the Academy, is well calculated to ſatisfy the public upon this point, and to encourage commerce.

2. Several docimaſtics, and among others Schundlen and Schlutter, have thought that the parted cornet of gold retained a little ſilver. They have given to this the name of *ſurcharge* or *inter-halt*. Meſſrs Macquer, Hellot, and Tillet, intruſted to examine the operation of the eſſayers of money, have proved, that it contained none of it. However, M. Sage aſſures us in his laſt work, entitled *the Art of Eſſaying gold and ſilver*, page 64, that

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within $\frac{1}{200}$ part of its fineneſs by means of touching needles. This conſtant experience gives the Chineſe merchants great advantage in this kind of traffic. But if thoſe who deal with them try the ſpecific gravity of the maſs in a hydroſtatical balance, they will barter upon better terms; becauſe gold, when pure, is the heavieſt of all metals; and when alloyed with ſilver alone, the mixture turns out exactly of the ſpecific gravity of the component metals, ſuppoſing no chemical union to have taken place. This, though a great convenience, is rather ſingular, as almoſt all mixtures of metals prove either heavier or lighter than what they ought to be by computation.

that gold in this ſtate retains always a little ſilver; and that it may be demonſtrated by diſſolving it in a dozen of parts of aqua regia; the ſolution being cooled, depoſites in a little time, often in a dozen of hours after making, a little luna cornea in the form of a white powder.

Gold is employed for a great number of purpoſes. Its ſcarceneſs and price prevent its being made uſe of for utenſils and veſſels as ſilver is: but as its brilliancy and colour are very agreeable to the ſight, art has found means of applying it to the ſurface of a great number of bodies, which it at the ſame time defends from the impreſſions of the air. This art conſtitutes in general gilding; of which there are many varieties. By means of glue, gold-leaf is often applied upon wood. Gold in a calx is prepared by braying with honey ſome gold-leaf, and waſhing it with water, and drying the molecules of gold which are precipitated. Gold in ſhells is the calx of gold intermixed with a mucilaginous water or a gummy ſolution. The following preparation gets the name of *gold en drapeaux*. Cloths are ſteeped in a ſolution of gold; they are dried and burnt. When they are wanted for uſe, a moiſtened cloth is put into the aſhes, and the ſilver is rubbed with it; which being very minutely divided, readily adheres. We have already ſpoken of gilding with painters gold. The copper to be gilt is well cleaned by means of ſand and a weak aquafortis, called *the ſecond water* by the workmen: it is put into a very dilute ſolution of mercury; and the mercury, which is precipitated upon it, makes the amalgam of gold adhere, which is ſpread over the piece after having been waſhed in water to carry off the acid. When the amalgam is uniformly ſpread, the piece is heated upon the coals in order to volatiliſe the mercury; the operation is finiſhed, by ſpreading upon the gold the wax for gilding, which is made up of red bole, verdegris, alum, or martial vitriol, incorporated with yellow wax, and by heating for the laſt time the gilded piece to burn off the wax.

The other uſes of gold for trinkets, laces, are well enough known to ſave the trouble of ſaying any more. As to the medicinal virtues attributed to it, ſkilful phyſicians at preſent refuſe it any; and think that the effects of the different potable golds, held out by the alchymiſts, are entirely dependent upon the ſubſtances in which it is mixed or diſſolved.

Species 15. PLATINA.

PLATINA, which was diſcovered only forty years ago for a paritcular metal, has been as yet found only in the gold mines of America, and in particular in thoſe of Santa-Fe near Carthagena, and of Bailliage de Choco in Peru. The Spaniards gave it this name from Plato, which ſignifies ſilver in their language, comparing it to this metal, whoſe colour it really poſſeſſes. However, the name of white gold ſeems to be more applicable than that of ſilver, approaching in moſt of its properties much nearer to gold than to ſilver.

Several jewels of platina exiſted before the epoch juſt now mentioned; but as this metal cannot be fuſed and wrought alone, it is probable that the ſnuff-boxes, the heads of canes, and other utenſils of this kind, which were ſold under the name of *platina*, were alloys of this metal with ſome metallic ſubſtances which communicated fuſibility to it, as ſhall be taken notice of in the hiſtory of its alloys.

Platina which is depoſited in cabinets, is in the form of ſmall grains or ſpangles of a livid white, whoſe colour inclines always to that of ſilver and iron. Theſe grains are mixed with ſeveral ſtrange ſubſtances: ſpangles of gold are found amongſt them; blackiſh martial ſand grains, which with the microſcope appear ſcorified like iron droſs; and ſome molecules of mercury.

This laſt metal is ſeparated by heat; waſhing carries off the ſand and grains of iron, which may likewiſe be ſeparated by the magnet; no more then remains but molecules of gold and grains of platina, which it is eaſy to pick out ſeparately, as M. Margraaf did. If grains of platina are examined with the microſcope, ſome appear angular, others rounded and flattened like cakes. Beat upon a ſteel maſs, the moſt part of them is flattened, and appears ductile; ſome break into ſeveral pieces. Theſe laſt, examined nearly, ſeem to be hollow, and in their heart pieces of iron and a white powder are found. There is no doubt but that upon theſe martial atoms, contained in ſome grains of platina, the property of being attracted by the magnet, found in theſe grains, depends, though they are ſeparated exactly from the ferruginous ſand which they contain. The purity of this metal ſeems to be very near that of iron. The ſpecific weight of platina, when mixed with all the other ſtrange matters juſt now mentioned, approaches much to that of gold; it loſes in water from a ſixteenth to an eighteenth of its weight. Meſſrs Buffon and Tillet, upon comparing by the weight an equal volume of platina and of gold, reduced into molecules ſimilar to thoſe of platina, found, that the ſpecific weight of platina was about one-twelfth leſs than that of gold. It comes near in ſpecific gravity to gold when it is purified by fuſion.

It is probable that platina is not found in the ores, ſuch as it comes to us; and that its granulous form depends only upon the operations to which the gold ores are ſubjected for the ſeparation of this laſt metal. As it is mixed always with gold, it is reduced to powder, and is even half poliſhed by the trituration which the gold ſuffers in the amalgamation with mercury. It is clearly on this account that it is always mixed with grains of gold and mercurial molecules.

Although platina jewels have been for a long time ſold, its particular properties were not known. The workmen in the mines had paid no particular regard to it, and had miſtaken a ſubſtance in whoſe appearance there was nothing flattering, and which, beſides, was of ſo difficult treatment. Don Antonio de Ulloa, a Spaniſh mathematician, who in the famous voyage accompanied the French academicians who were ſent to Peru to determine the figure of the earth, was the firſt perſon to whom we owe the chief knowledge of platina. He ſays a few words about it in the relation of his voyage publiſhed at Madrid *anno* 1748. Mr Charles Wood, an Engliſh metallurgiſt, brought ſome of it from Jamaica, *anno* 1741. He accordingly examined it; and has given an account of his experiments in the Philoſophical Tranſactions for the years 1749-50. At this time, ſeveral of the moſt famous chemiſts in Europe anxiouſly ſet about the examination of this new metal, which promiſed ſo many advantages by its ſingular properties. M. Scheffer, a Swediſh chemiſt, publiſhed his obſervations upon platina, in the Memoirs of the Academy of Stockholm for the year 1751. M. Lewis, an Engliſh chemiſt, gave a ſubſequent, and almoſt complete, deſcription of this metal: it is to be found in the Philoſophical Tranſactions, *anno* 1754. M. Margraaf, in the Memoirs of the Academy of Berlin, has given an account of his experiments upon this new metal. The greateſt part of theſe particular memoirs has been collected by M. Morin, in a work intitled, *Platina, White Gold, or the Eighth Metal*, Paris, 1758. At the ſame time, M. Macquer and Baumé made together a great number of important experiments upon platina, which have been publiſhed in the Memoirs of the Academy for the year 1758. M. de Buffon has related, in the firſt volume of the Supplement to his Natural Hiſtory, a ſet of experiments upon platina, made by himſelf, M. Morveau, and the Count de Milly. And, laſtly, M. le Baron de Sukengen alſo undertook an inveſtigation of the metal. From the accounts given by theſe philoſophers, we ſhall borrow the greateſt part of the hiſtory of the chemical properties of platina.

Platina, expoſed to the moſt violent fire of our furnaces, ſuffers no kind of alteration; only it agglutinates a little. All the chemiſts who have made experiments upon this metal agree in this point. M. Macquer and Baumé kept ſome of it expoſed ſeveral days to the continued fire of a glaſs-houſe furnace, without its grains ſuffering any alteration except that of joining ſlightly to one another; this agglutination was even ſo weak, that a ſmall force eaſily ſeparated them. In theſe experiments they obſerved the colour of platina become brilliant when it was in a white heat; that it aſſumed a dull grey colour when it was long heated; and, laſtly, that it increaſed conſtantly in weight, as M. Margraaf had ſaid, which could ariſe only from the calcination of ſome ſtrange ſubſtances which are mixed with it. Theſe chemiſts expoſed ſome platina to the focus of a great burning mirror: it began to fume; it gave vivid and very ardent ſparks; laſtly, the portions of this metal, expoſed to the centre of the focus, were fuſed in a minute. The fuſed portions were of a white brilliant colour, and preſented the form of a button: they could be cut into laminæ with a knife. Struck upon a piece of ſteel, one of them was flattened, and reduced into a thin plate, without cracking or ſplitting; it was ſtiffened with the hammer. This elegant experiment ſhows us, that platina is fuſible by a fire of the moſt extreme force; that it is as malleable as gold and ſilver; and that it is unalterable by the action of the fire; for in all theſe experiments, the moſt part of which were made in the open air, platina exhibits no ſigns of calcination. M. de Morveau alſo fuſed platina by making uſe of the air-furnace deſcribed by M. Macquer, with his reductive flux, compoſed of eight parts of pounded glaſs, one part of calcined borax, and a half of pounded charcoal.

Platina expoſed to the air is nowiſe changed. However,

ever, it is not known what might be the effect by a long-continued red heat with acceſs of air: perhaps it would be calcined, as Juncker aſſerts gold and ſilver are when treated in the ſame way.

This metal ſuffers no alteration from water, the earthy, ſaline-earthy, nor alkaline ſubſtances.

The moſt concentrated vitriolic acid, the ſtrongeſt and moſt fuming nitrous and marine acids, even when they are aſſiſted by a boiling heat, have not the leaſt action upon platina; nor does diſtillation, ſo efficacious a means with all the chemiſts for favouring the action of the acids upon the metallic ſubſtances, promote their action; only, according to Meſſrs Lewis and Baumé, the vitriolic acid tarniſhes its grains. The nitrous acid, on the contrary, renders it brilliant. M. Margraaf ſays, that, at the end of the diſtillation of this acid with platina, he obtained ſome arſenic; a phenomenon which other chemiſts have not taken notice of. The marine acid does not change it in the leaſt degree. M. Margraaf likewiſe obtained from this acid, diſtilled from this metal, a white ſublimate, which appeared to him to be arſenic; and a reddiſh ſublimate, the properties of which he could not examine on account of its too ſmall quantity. All theſe ſubſtances evidently appear foreign to platina. This metal then reſembles gold in the ſmall action which the ſimple acids have upon it; but this analogy is ſtill more remarkable in its ſolubility in aqua regia.

The aqua regia which diſſolves platina the beſt, is a compoſition of equal parts of nitrous and marine acids. To make this ſolution, which is in general more difficultly made than that of gold, an ounce of platina muſt be put into a retort with a pound of the aqua regia deſcribed; the retort is ſet in a ſand-bath, and a recipient is adapted. As ſoon as the acid is hot, ſeveral bubbles ariſe from the mixed acid, which is beginning to act upon the platina: the gas diſengaged has not been examined. It ſeems not to be copious: the action of the menſtruum goes on without violence or rapidity;

mean time, it aſſumes at firſt a yellow, which paſſes to an orange colour, and deepens gradually, becoming of a very obſcure brown red. When the ſolution is finiſhed, ſome reddiſh and black ſand is found at the bottom of the retort, which is ſeparated by decantation: the liquor, when ſaturated, depoſites gradually ſmall ſhapeleſs cryſtals, of a fallow colour, which are a combination of acid and platina. The ſolution of platina is one of the moſt coloured metallic ſolutions; though it appears of a deep brown, if it is diluted with water it aſſumes at firſt an orange colour, which very ſoon becomes yellow, and very ſimilar to the ſolution of gold: it ſtains animal-matters of a blackiſh brown, but not at all purple. M. Baumé ſays, that platina, fuſed with the focus of a burning-glaſs, when diſſolved in aqua regia, never aſſumes a brown colour like that of platina grains, and that this ſolution is of a deep orange yellow.

M. Macquer aſſerts, that in evaporating the ſolution of platina, and allowing it to cool, much larger and much more beautiful cryſtals are obtained than thoſe it depoſites when it is ſaturated. Mr Lewis having allowed this ſolution to evaporate in the open air, obtained cryſtals of a deep red, tolerably large, of an irregular figure, reſembling benzoin flowers, though they were more thick. This ſalt is ſharp, and not cauſtic; it partly melts, allows its acid to diſſipate, and for a reſiduum gives an obſcure grey calx. Concentrated vitriolic acid occaſions a precipitate of a deep colour, which is undoubtedly a vitriol of platina. The marine acid in ſome time produces a yellowiſh depoſition.

The alkalis and ſaline-earthy ſubſtances decompoſe the ſolution of platina, and precipitate this metal in the ſtate of a calx. Mild fixed alkali occaſions an orange precipitate. This precipitate is not the pure calx of platina. Meſſrs Macquer and Baumé have obſerved, that it owes its colour to a certain quantity of acid which it contains. Its colour is then to be conſidered as depending upon a portion of calx and a portion of ſalt of platina

mixed

mixed together. This opinion is proved; becauſe, by waſhing the precipitate with hot water, this fluid is coloured by diſſolving the ſalt of platina; and the reſiduum, which is a pure calx of this metal, is grey. The fixed alkali, boiled upon this precipitate, readily carries off its colour by decompoſing the ſalts, and leaves a calx of platina, which is of a pearl-white colour, according to the experiments of M. Baumé. This chemiſt convinced himſelf of the ſolubility of the precipitate of platina in the alkali, by pouring, drop by drop, the ſolution of this metal into hot fixed alkali, no precipitate falling down. It is on this account that this ſolution, precipitated by the fixed alkali, retains always a deep colour; and the platina is eaſily obtained by evaporation to dryneſs. M. Margraaf diſcovered, that the mineral alkali did not precipitate the ſolution of platina: this phenomenon is ſurely owing to the immediate rediſſolution of the platina in the alkali. The alkali, ſaturated with the colouring part of Pruſſian blue, forms a copious blue precipitate, which, according to M. Baumé, is owing to the iron contained in the alkali; ſince, if Pruſſian alkali is employed, which is deprived of the iron which it contains by means of the proceſs mentioned by this chemiſt, it gives with the ſolution of platina only a few atoms of blue, owing to the ſmall portion of iron which this metal always contains. The Pruſſian volatile alkali forms two precipitates in this ſolution, as Mr Lewis has obſerved; one, which is yellow and very copious, occupies the inferior part of the mixture; the other is blue, and above it. This laſt is ſo ſcanty, that it diſappears upon agitation.

The volatile cauſtic alkali precipitates platina of an orange yellow. This precipitate is almoſt entirely ſaline; the greateſt part diſſolving in the water, and becoming coloured, like a ſolution of gold. After the action of the water upon this precipitate, a blackiſh ſubſtance remains, which appears to be ferruginous. There is this great difference between the precipitate of platina

tina and that of gold by the volatile alkali, that the firſt does not fulminate as the ſecond does.

The gall-nut precipitates platina of a deep green, which turns pale gradually by repoſe.

All the precipitates obtained from the ſolution of platina by means of the alkaline ſubſtances, are not ſuſceptible of vitrefication and of colouring glaſs. In the trials which Meſſrs Lewis and Baumé made to this purpoſe, the platina was always reduced into ſmall grains, into ramifications, or reſemblances of lace. A kind of button of platina may be obtained, by ſubjecting theſe precipitates to the action of ſome reductive fluxes, as borax, cream of tartar, glaſs. Meſſrs Macquer and Baumé, in thirty-five minutes, fuſed a precipitate of platina, mixed with fluxes, by a fire of a forge blown with two bellows. Under a hard blackiſh glaſs, reſembling that of bottles, they obtained a brilliant button of platina, which appeared to have been well fuſed. This button was not ductile; it was broken into two pieces; the internal part of which was hollow. This metal preſented a granulated texture and coarſe fracture: it was nearly as hard as forged iron, and it ſcratched deeply gold, copper, and even iron. Although we have ſaid that the precipitates of platina did not appear ſuſceptible of vitrefication or mixture with glaſs, M. Baumé, however, fuſed them into a vitreform matter by two different proceſſes. The precipitate of platina, mixed with borax and a very fuſible white glaſs, and expoſed for thirty-ſix hours to the hotteſt place of a potter's furnace, produced a greeniſh glaſs, inclining to yellow, without the appearance of metallic globules. This glaſs, heated with cream of tartar in a violent fire, exhibits the platina reduced into grains, which it has ſeparated from the blackiſh glaſs in which they were diſperſed, by pulveriſation and waſhing. This chemiſt, along with M. Macquer, then expoſed the precipitate of platina to the focus of the ſame burning mirror with which they had fuſed this metal,

metal. This precipitate exhaled a very thick and very luminous ſmoke, which ſmelled ſtrongly of aqua regia: it loſt its red colour, and reſumed that of platina, and was fuſed into a ſmooth brilliant button, which was only an opaque vitreſcent matter, of a hyacinth colour at its ſurface, and blackiſh internally; which may be conſidered a true glaſs of platina. It is neceſſary, however, to obſerve, that the ſaline matters with which it was impregnated, contributed without doubt to its vitrefication.

The precipitate of platina does not appear to be ſoluble in the ſimple acids: but it diſſolves very well in aqua regia; to which it gives only an orange colour, never coming up to the brown which platina in grains exhibits.

The ſolution of platina is not precipitable by the alkaline or perfect neutral ſalts; but ſal ammoniac occaſions a copious depoſition. It is not yet quite certain what happens here. It appears that the orange precipitate, which is obtained by pouring a ſolution of ſal ammoniac into a ſolution of platina, is a true ſaline ſubſtance, entirely ſoluble in water. A very important property was diſcovered in this precipitate by M. de Liſle; which is its fuſibility *per ſe*, and without addition, with a ſtrong fire of a furnace, or of that of an ordinary forge. Platina fuſed by this proceſs is in the form of a very denſe and compact brilliant button; but it loſes malleability, and does not become ductile, till it is expoſed to a very intenſe heat. M. Macquer thinks, that the ſame thing happens in this fuſion as in the fuſion of platina in grains when expoſed to the action of a violent fire; that it is only an agglutination of the ſoftened molecules; which, being infinitely more divided and more ſubtile than the grains of platina, approach nearer, and touch one another in many more points, than they do: which circumſtance renders the texture of this metal much more compact, although it has undergone no true fuſion. However,

ever, let us obſerve, that if platina in grains fuſes with a burning lens, and acquires a very conſiderable ductility, the precipitate of this metal by ſal ammoniac may as well be fuſed on account of its extreme diviſion; and that if it is not as ductile as the button of platina fuſed by the rays of the ſun, it depends perhaps upon the retention of ſome matter which it has carried along with it in its precipitation, of which it may be deprived by the action of fire.

M. Margraaf diſſolved platina in an aqua regia compoſed of ſixteen parts of nitrous acid and one part of ſal ammoniac. Upon diſtilling this ſolution to dryneſs, and till the bottom of the retort was red, a ſalt of a deep red was ſublimed; and the reſiduum was in the form of a reddiſh powder. It is not known if, from the ſolution of platina in a ſimple aqua regia, that is, made with pure nitrous and marine acids, the ſame ſublimate would be obtained by diſtillation.

Meſſrs Margraaf, Baumé, and Lewis, mixed the ſolution of platina with ſolutions of all the other metallic ſubſtances. The reſult of their experiments is, that almoſt all the metals precipitate platina in the form of a brick-red or brown powder; and that each of theſe precipitates enjoys metallic properties, as is the caſe with moſt of the other metals. This is an analogy which exiſts alſo between gold and platina, although this laſt does not with tin give a purple colour as gold does, but rather a brown precipitate, inclining to red. With reſpect to the effect of the different metallic ſolutions upon platina, it will be ſufficient to obſerve, that biſmuth and lead in the nitrous acid, iron and copper in the different acids, and gold in aqua regia, produce no precipitate in the ſolution of platina, according to M. Margraaf; and that, on the contrary, the ſolutions of the arſenical neutral ſalt, zinc, and ſilver, by the nitrous acid, precipitate it; the firſt, in a cryſtalliſed ſubſtance, not copious, of a fine golden colour; the ſecond, in an orange red matter; and the third, in a yellow-coloured matter: theſe different precipitates have not yet been properly examined, nor is the decompoſition occaſioned underſtood.

The moſt part of the neutral ſalts have no action upon platina. M. Margraaf, in a violent fire, heated platina with vitriolated tartar and Glauber's ſalt: the ſalts were fuſed, and the platina remained in grains without alteration: it had communicated only a ſmall reddiſh colour to the ſaline matters, no doubt from the iron with which it was mixed.

Nitre alters platina in a ſingular manner, according to the experiments of Meſſrs Lewis and Margraaf. Although it does not detonate with platina when a mixture of theſe ſubſtances is projected into a red hot crucible; however, upon the application of a ſtrong and long-continued heat, ſuch as Mr Lewis uſed for three days and nights ſucceſſively to a mixture of one part of platina and two of nitre, the metal acquires the colour of ruſt. If the mixture is boiled in water, the alkali is diſſolved, and carries along with it a browniſh powder; and the platina ſeparated from this ley is found diſſolved more than a third. The brown powder is ſeparated by filtration. This powder ſeems to be a kind of calx of platina mixed with a little crocus martis. Mr Lewis at laſt gave this calx a whitiſh-grey colour by repeated diſtillations with ſal ammoniac. M. Margraaf, who repeated this excellent experiment, has added two important facts; the one is, that the platina combined with the alkali of the nitre, and diluted with a certain proportion of water, forms a gelly; and the other, that upon calcining the portion of this metal ſeparated from this gelly, diluted with water, and filtrated, it took a black colour like pitch. This experiment announces a great alteration in the platina; and it would be of great conſequence to continue the experiment, to ſee if, by the force of repeated calcinations with nitre, it would be poſſible to reduce all the metal into a brown powder, like that of which we have been ſpeaking; and in particular to determine the ſtate of the platina thus calcined.

Marine, febrifugal, boracic, and earthy ſalts, produce no alteration upon platina, nor facilitate its fuſion. Sal ammoniac, diſtilled with this metal, gives a few flores martiales from the iron which the platina contains.

Chemiſts are not agreed upon the reciprocal action of arſenic and platina. M. Scheffer ſays, that arſenic fuſes this metal: but the experiment did only in part ſucceed with Mr Lewis, and not at all with Meſſrs Margraaf, Macquer, and Baumé.

The combination of platina with cobalt, nickel, and manganeſe, never has been tried.

This perfect metal alloys very well with biſmuth; which renders it the more fuſible the greater the quantity of this laſt.

This alloy is brittle: it becomes yellow, purple, and blackiſh by the air: it cannot be cupelled without the greateſt difficulty: it forms a maſs always of little ductility.

Platina fuſes eaſily with regulus of antimony: a brittle metal in facets reſults; from which the regulus cannot be ſeparated by fire, but it retains always enough of it to render the platina more light and brittle.

Zinc renders platina very fuſible, and combines eaſily with it. This metal is brittle and hard to the file: it inclines to a blue when the platina is more abundant than the zinc. They are ſeparated by heat, which volatiliſes the zinc: platina, however, always retains a little of it.

Platina does not unite nor form an amalgam with mercury, notwithſtanding ſeveral hours trituration. The ſeparation of gold from platina, beſides, is known to be practiſed in America. Several intermedia, ſuch as water, employed by Meſſrs Lewis and Baumé, and aqua regia by M. Scheffer, do not facilitate in any degree their union: this property ſeems to bring it near to iron, whoſe colour and hardneſs it already poſſeſſes.

Platina alloys very well with tin. This alloy is very fuſible, and runs eaſily. It is brittle and fragile even by a ſtroke, when equal parts are employed. When the tin is in the doſe of a dozen, and even more parts, to one of platina, this mixt metal is very ductile; but it has an unpoliſhed and coarſe grain, and it turns yellow with the air. Platina remarkably diminiſhes the ductility of tin, and appears incapable of ſeparation from this alloy: however, when it is well poliſhed, it may remain a long time without alteration by the air. Mr Lewis, to whom we are indebted for almoſt all our knowledge of the alloys of platina, ſeems to have ſucceeded in its calcination, and in diſſolving it in marine acid by means of tin.

Platina and lead unite very well by fuſion; for which a ſtronger fire is neceſſary than the preceding alloy requires. Platina deprives lead of ductility. From their combination a mixt metal reſults, inclining to purple, more or leſs brittle according to the proportion of platina, ſtriated and granulated in its texture, and readily altered by the air. Cupellation was one of the moſt important experiments to be made upon platina; indeed this operation was alone capable of purifying it from the ſtrange metals which it might contain. Mr Lewis, and ſeveral other chemiſts, have in vain attempted to cupel platina in the ordinary cupelling furnaces, however intenſe the heat might be which they produce; the vitrefication and abſorption of the lead took place in the commencement of the operation, on account of the exceſs of the fuſible metal: but in proportion as this laſt diminiſhes, the platina reſumes its infuſibility which it communicates to the laſt portions of the lead, ſo that it fixes upon the cupel, and weighs more after the operation than before it, on account of the lead which it retains. Meſſrs Macquer and

Baumé, however, have ſucceeded in the complete ſeparation of the lead. They expoſed upon a cupel an ounce of platina and two ounces of lead in the hotteſt place of a furnace for baking porcelain of Sèves. The fire of wood applied continues fifty hours. At the expiration of this time, the platina was flattened upon the cupel; the ſuperior ſurface was dull and wrinkled; it was eaſily taken off; its inferior ſurface was brilliant; and, what is of more conſequence, it was capable of extenſion by the hammer. This chemiſt was convinced, that this platina contained no lead, and that it was very pure. M. de Morveau likewiſe ſucceeded in cupelling a mixture of one gros of platina and two of lead, by employing the furnace with M Macquer's vent. This operation continued from eleven to twelve hours, and was repeated four times. M de Morveau obtained a button of platina, not adhering, uniform, of a colour reſembling that of tin, a little rough, which weighed a full gros, and ſeemed nowiſe affected by the magnet. This then is a proceſs calculated to obtain platina fuſed into plates, which may be forged, and be conſequently employed for different precious utenſils, on account of their hardneſs and unalterability. M. Baumé has alſo taken notice of a very uſeful property, that of being ſoldered and forged like iron, without the aſſiſtance of any other metal. After the application of a white heat to two pieces of platina, which had been cupelled in a furnace of ſèves, he placed them on one another, and ſmartly ſtruck with a hammer; they were as completely and ſolidly ſoldered as two pieces of iron would have been. We need not ſay any more upon this experiment, to ſhow the advantages which will hence accrue to the arts.

Mr Lewis could not obtain an alloy of forged iron and platina. This mixt metal might have the great advantage of uniting the hardneſs of ſteel with a great ductility; at leaſt it would not be fragile and brittle like ſteel. This Engliſh chemiſt fuſed a mixture of caſt iron and platina. This alloy was ſo hard, that a file could not affect it: it had ſome ductility, but broke clean when it was red.

Platina gives hardneſs to copper, with which it very eaſily fuſes. This alloy is ductile when the proportion of the copper is three or four parts to one of platina. It is ſuſceptible of a fine poliſh, and does not tarniſh when expoſed to the air in ten years.

Platina in part deſtroys the ductility of ſilver, augments its hardneſs, and tarniſhes its colour. This mixture is very difficultly fuſed; the two metals ſeparate by fuſion, and repoſe. Mr Lewis obſerved, that ſilver, fuſed with platina, is thruſt to the ſides of the crucible with a kind of exploſion. This phenomenon ſeems to belong to the ſilver alone, as M. d'Arcet ſaw this metal break little porcelain veſſels in which it was contained, and driven above theſe veſſels by the action of heat.

Platina does not readily combine with gold without an intenſe heat. It greatly alters its colour, unleſs it be in very ſmall quantity; for inſtance, a forty-ſeventh of platina, and all inferior proportions, make no great alteration upon gold. Platina changes the ductility of gold only in a ſmall degree: it is indeed one of the metals which change it in the leaſt degree. The weight of platina, which is almoſt equal to that of gold, might be favourable to deceit; and on that account the Spaniſh premier ſhut up the ores of platina. However, ſince the diſcoveries in chemiſtry of the teſts for detecting ſuch fraud, of gold alloyed with platina, and even platina alloyed with gold, all apprehenſions may be given up; and it is ſtrongly to be wiſhed that the mines of platina were opened, that ſociety might reap, by commerce, thoſe advantages which this new metal promiſes.

The ſolution of ſal ammoniac, as we have ſeen, has the property of precipitating platina. If, then, gold is ſuſpected of being alloyed with platina, we may try its ſolution in aqua regia with a ſolution of ſal ammoniac; the little platina which it contains, will occaſion an orange or reddiſh precipitate: if there is no precipitate, it is a proof that the gold contains no platina. If it happens that the excellent properties of platina ſhould render it every day more rare and more deſirable than gold, avarice could not deceive us more eaſily by alloying gold with this metal, as a ſolution of martial vitriol, which has the property of precipitating gold without changing that of platina in any way, would inſtantly diſcover the fraud. A lamina of tin, immerſed into a ſolution of platina alloyed with gold, would alſo diſcover this laſt, by being covered with a purple precipitate; whilſt platina gives it only a brown colour inclining to red; beſides, this laſt precipitate does not colour glaſs, whereas the precipitate of gold gives it a purple colour.

All the properties of platina which we have pointed out, ſeem to prove, that this ſubſtance is a particular metal, the moſt perfect and moſt unalterable of them all. Its ſmall ductility and infuſibility, by ſome conſidered as two ſtrong objections againſt this opinion, cannot, however, refute it; ſince there is perhaps leſs difference between the fuſibility of platina and that of forged iron, than there is between the fuſibility of forged iron and that of lead; and ſince its little ductility, hitherto known, depends only upon the incomplete fuſion which it has been made to undergo. As to the opinion of the learned philoſophers, who look upon platina as an alloy of gold and iron, however ingenious and ſatisfactory it may appear, it cannot be admitted; for this metal will not ſeparate into two by an accurate analyſis; and at preſent platina cannot be imitated by artificially alloying gold and iron. Laſtly, M. Macquer has made a very ſtrong objection to this laſt opinion, obſerving, that the more completely platina is freed of the iron which it contains, the more it differs from the external characters and properties of of gold

It is ſufficiently underſtood of what important uſe this precious metal might be, if introduced into commerce, ſince it unites the indeſtructibility of gold with a hardneſs almoſt equal to that of iron; baffles the action of the moſt intenſe heat, and of the moſt concentrated acids. The arts and chemiſtry would doubtleſs reap vaſt advantages from it *.

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* All metals owe their fluidity to heat, and are found in a ſolid or in a fluid ſtate, according as the intenſity of the heat is augmented or diminiſhed. Even platina and mercury have proved ſubject to this general law; from which they were long ſuppoſed to be exempted. More accurate and recent experiments have ſhown, that platina may be fuſed without addition by the action of heat alone, and that mercury may be congealed into a ſolid maſs by expoſure to a ſufficient degree of cold. The fuſion of platina, and the congelation of mercury, require the moſt intenſe degrees of heat and of cold which it is in the power of art to produce. Metals ſuffer no change from the mere act of fuſion, but are found, after they have cooled, to be quite unaltered, and to be the ſame in every reſpect as they were before melting. Many metals, in paſſing from a fluid to a ſolid ſtate, loſe their heat ſo gradually as to paſs into an intermediate degree of coheſion, where ſome part is fluid and ſome part ſolid, and where the whole maſs bears a diſtant reſemblance to a parcel of wet ſand. Lead is the moſt remarkable of metals for this property: other metals inſtantly congeal upon loſing their heat, and paſs from a fluid to a ſolid ſtate with a very ſudden tranſition, as water into ice. In ſome caſes, the external ſurface of the metal congeals, while the more internal parts continue fluid. This happens in the cupellation of ſilver with lead: the moment the whole lead is ſcorified and abſorbed by the cupel, the ſame degree of heat is no longer able able to keep the ſilver in fuſion; ſo it congeals on the ſurface; and as the hardened ſhell of ſilver contracts during congelation, the fluid metal within is ſqueezed out through different crevices, and forms what is called *the vegetation of the button.*

The contraction of ſilver during congealation is a property common to it with moſt other metals. Gold is very remarkable in this reſpect. It ſeems, when in fuſion, to riſe in the crucible with a convex ſurface as it melts, and to contract very greatly as it fixes in the mold. But though this be the general caſe, there are ſome exceptions to be remarked, in which metals expand upon cooling. Biſmuth and iron expand in fixing; ſo that a piece of cold iron will float on the ſurface of melted iron: and on account of this property biſmuth is added to compoſitions of type-metal, to give a ſharp impreſſion from the mould.

All metals, when in fuſion, become ſolvents, and are capable of diſſolving ſome other metal. But they are not able to diſſolve any other kind of matter, neither earths nor metallic calces; nor is there any calx which is ſoluble in the metal from which it was made. Thoſe caſes in which a ſolution, or even a mixture, was ſuppoſed to take place between a calx and a metal, are entirely founded upon a miſconception of the fact. When iron is ſaid to unite with the white calx of arſenic by fuſion, we entirely overlook the change which happens before the union. There is in this combination a regular ſeries of chemical proceſſes performed. The arſenic firſt calcines a portion of the iron, becomes a regulus itſelf, and in this ſtate combines with the metallic iron, while the martial calx is rejected from the mixture: ſo that the inſtance of arſenic and iron, inſtead of being an exception to the general rule, proves the ſtrongeſt confirmation of its truth. But when every obſtacle is removed, and two metals are combined by the aſſiſtance of heat, we obtain a mixture, poſſeſſed of properties which we would not expect to reſult from the union of the component metals. The mixture is termed an *alloy;* and we find univerſally, that all alloys are more fuſible than either of the metals of which they are compoſed. By the addition of gold to iron, an alloy is formed of very eaſy fuſion: and Mr Roſen mentions a mixed metal, conſiſting of lead, zinc, and biſmuth, which will melt with a heat not exceeding that of boiling water. The fuſible mixture of Sir Iſaac Newton has long been known to chemiſts, tho' it requires a greater degree of heat than the compoſition mentioned by M. Roſen. When we compare the fuſibility of alloys with the infuſible quality of compound ſtones, and conſider that all ſimple earths are quite unalterable by heat, but that they acquire a fuſibility by mixture with each other; we perceive an analogy, which may at laſt lead to a diſcovery of the cauſe upon which the whole reſts.

The ſpecific gravity of alloys is but rarely the intermediate gravity of the two metals. In moſt caſes it proves heavier than computation, in others lighter. But what is moſt worthy of notice, we often find the alloy heavier than the heavieſt of the two metals of which it is compoſed; as proves to be the caſe in mixture of tin with copper, and in many other alloys. On the contrary, other alloys turn out ſpecifically lighter than the lighteſt of the two metals, as we are told happens in many mixtures of platina with other metals. All the phenomena are very ſtriking, and deſerve the moſt ſerious conſideration to inveſtigate their cauſe. They clearly demonſtrate a moſt intimate penetration of parts, and a complete chemical ſolution and union of the integrant parts of the metals with each other; they ſhow the futility of truſting to the ſpecific gravity of an alloy to judge of the proportional quantities of known component metals. If we ſhould even attempt to form tables of ſpecific gravity by computation,

putation, we muſt beware leſt we fall into an error in the mode of our computing. It is a capital miſtake, and makes an eſſential difference in the reſult, to ſubſtitute equal weights inſtead of equal bulks. To underſtand the proof of this, let us take an example of two metals; the ſpecific gravity of one of which we ſhall ſuppoſe 9, and of the other 18. The ſpecific gravity of an alloy of equal bulks, conceived to be mechanically mixed, will prove an arthmetical mean of $13\frac{1}{2}$; becauſe $9+18=27$; the weight in air being divided by 2, the loſs which the component metallic ſubſtances ſuſtain by weighing in water, is $=13\frac{1}{2}\ \frac{27}{2}=13\frac{1}{2}$. But if, inſtead of equal bulks, we aſſume equal weights, then as 18 parts of the heavier metal loſe 1, and 18 of the lighter loſe 2, the mixture of both will loſe exactly 3 parts, and the ſpecific gravity of the mixed metal will be $\frac{36}{3}=12$, greatly leſs than the other mode of computation. Errors of this kind are ſo frequently committed by chemical calculators, that it is proper every perſon be appriſed of them, before he undertakes a ſet of experiments upon the ſubject.

The effects of metals in an alloy are not reciprocal upon each other. For although the addition of gold or of ſilver to lead or tin, renders both theſe baſe metals vaſtly more fuſible, yet the ſmalleſt impregnation of lead or tin will impair the ductility of gold and ſilver in a wonderful degree. So remarkable is the effect of tin in debaſing the ductile quality of gold, that even the vapours of a ſingle grain of tin will render a whole pot-full of gold quite brittle and uſeleſs, as workmen often experience to their coſt; who are frequently compelled, on this account, to pull down a brick furnace and rebuild it, in order to remedy the defect.

Metals ſeem only to be miſcible with each other in certain proportions, and to have a fixed point of ſaturation, in the ſame way as the mixture of other ſubſtances; though it is a difficult matter to determine the fact by a regular ſet of experiments. They ſhould alſo ſeem to admit of different degrees of intimacy in their union; as ſome of them, though to all appearance completely blended together, may be ſeparated by the mere effect of heat, without the aid of chemical attraction. This is the caſe in many compoſitions with copper. When mixed with lead, it may be ſeparated by eliquation; that is, by expoſing the alloy to a degree of heat ſufficient to fuſe the lead, but not to melt the copper; ſo that the liquid lead may run off from the pores. In the ſame way the zinc may be entirely conſumed from braſs, and the copper reſtored to its original purity. Had the incorporation of thoſe metals been very complete, they ſhould have come into fuſion at one time, as gold and iron, though poſſeſſed of very different degrees of fuſibility. It is indeed very difficult to mark all the gradations in the ſcale of union among metals, as their incorporation may be more or leſs perfect, and they may be either chemically diſſolved by a thorough penetration of parts, or only mechanically mixed together. When two metals poſſeſs very nearly the ſame degrees of fuſibility, their parts may be ſo thoroughly blended by heat, as to aſſume the appearance of a perfect alloy. Thus the alloys of gold and ſilver would ſeem to be nothing more ; for if an eſſay be made of different parts of the maſs, it is found to conſiſt of an unequal proportion of ingredients : and when kept fuſed for ſome time in a crucible, they ſeparate from each other, the gold falls to the bottom, and the ſilver floats a-top, from their difference of ſpecific gravity. In order to form ſome judgment, whether two metals be chemically diſſolved, or only mechanically mixed, we ſhould attend to the following circumſtances. If the mixed maſs poſſeſs an intermediate ſpecific gravity, be of an intermediate colour and ductility, and be ſeparable by heat alone ; we may then ſafely conclude, that they are only mechanically mixed : but if the colour, ductility, and ſpecific gravity, be very different from that of the component metals, and they are totally inſeparable by heat, we have then juſt reaſon to believe in a moſt complete chemical ſolution.

Alloys are uſeful to obtain the exact combination of properties which we wiſh a metal to have. They are uſed in braſs, type-metal, bell metal, pewter, optical ſpecula, and many other purpoſes in life.

In the converſion of metals into calces, by expoſure to the influence of heat and air, we meet with a diverſity of character in the different metals. Some of them endure a great heat before they begin to calcine ; ſome calcine eaſily, but far from completely ; and ſome calcine both eaſily and moſt perfectly. Copper and iron ſuſtain a violent heat before they throw off ſcorified ſcales. Biſmuth and lead ſoon loſe their metallic appearance, but are not afterwards reduced to the ſtate of perfect calces : whereas tin and antimony are both of them moſt perfectly calcined in a ſhort time, and with no great degree of heat. Thoſe varieties ſuggeſt ſome radical differences in the conſtitution of the metals, which our knowledge of the ſubject has not hitherto been able to explain. The calces of moſt of them are convertible into glaſs ; and this diſpoſition to vitrefy ſeems to be intimately connected with the degree of calcination which they have ſuſtained. When the calcination is very complete, the calx cannot be made to vitrefy by any degree of heat. Upon this account we find the calx of tin, and the diaphoretic calx of antimony, quite infuſible : but when the calx of antimony is mixed with any of the reguline metal, it is then brought into a ſtate capable of vitrefication. The calx of tin cannot be made to vitrefy by any chemical treatment, unleſs it be mixed with ſome very powerful flux. Even with the moſt proper additions it is not eaſily fuſed, and never flows thin, or forms a very perfect glaſs. Litharge, on the contrary, which is the glaſs produced from lead, is not capable of being converted into an earthy calx. It never loſes the appearance of a glaſs, and is very eaſily reſtored into the form of a metal. In the ſtate of calces, we formerly obſerved, that the metallic earths were not miſcible with metallic reguluſes ;

luſes: but in this ſtate they readily unite with all earths, promote their vitrification, and are the moſt powerful fluxes. Glaſs of lead is on this account commonly employed to ſcorify ores, and to ſeparate the metallic matters from the matrix and mineralizing earths. Other calces, which are not ſo fuſible, and which do not eaſily vitrefy, form the baſes of enamels or imperfect glaſſes. Putty, the calx of tin, is uſed in the formation of white enamel: and all colours which muſt withſtand a violent heat, burnt into veſſels of porcelain, enamel, or glaſs, are prepared from the calces of ſome metal or other.

All metals are not ſubject to calcination by the effects of heat and air, as we find that gold, ſilver, and platina, are exempted from their influence; though thoſe three perfect metals, and every other metallic ſubſtance, may readily be calcined by ſolution in an acid menſtruum. Some ſpecies of an acid in a liquid form, either ſimple or mixed, is to be found capable of diſſolving any given metal; and the metal is afterwards to be obtained in form of a calx, either by evaporation to dryneſs, and expulſion of the acid by heat; or, if the end be not attainable in this way, it will be by precipitating the metallic earth by means of an alkaline ſalt. Metallic earths, in this degree of calcination, are eaſily diſſolved in the acids from which they fell, and even become ſoluble in weaker acids which had no power over them before, and could not be made to diſſolve them in a reguline form. What change they have undergone to prepare them for more ready ſolution, will appear by conſidering the action of acids upon manganeſe. It is ſufficiently known, that the addition of ſome inflammable ſubſtance is requiſite to promote the ſolution of black manganeſe in acid menſtrua. The manganeſe ſoon becomes ſoluble, falls from the acid in form of a white precipitate, and may thereafter be reſtored to its former blackneſs by ſufficient calcination: ſo that this white precipitate is leſs calcined, and approaches more nearly to the ſtate of a regulus, than the black manganeſe. From theſe appearances, we are led to conclude, that tho' all metals muſt be ſomewhat calcined before acids can diſſolve them, they muſt not be too much ſo; and that there is ſome intermediate degree which anſwers the purpoſe of ſolution beſt. Before the confirmation of theſe facts, we knew that metals might be too highly calcined to be readily ſoluble in acids; but we had no direct proof that this power was recoverable by a nearer approximation to a metallic ſtate. There are indeed many facts which ſerve to illuſtrate this principle; as, for example, a ſolution of iron, which becomes turbid when expoſed to the air, from the precipitation of an ochry matter. This is no more than the metal becoming too much calcined to be longer capable of ſuſpenſion in the acid. Other proofs might be given, if the doctrine were now not thoroughly eſtabliſhed, and if it were not certain, that neither reguline metals, nor perfect calces, are ſoluble in their proper menſtrua. The degree of calcination which metals muſt undergo, varies in different caſes; and is affected by circumſtances of the ſolution of the ſame metal in the ſame acid, and may be more or leſs calcined and yet perfectly diſſolved. We know that nitrous acid will diſſolve mercury in the cold; and after the action has ceaſed, the aſſiſtance of heat will enable the acid to diſſolve more. Now, what is laſt taken up is in a metallic form; and the proof of the opinion is, that calomel may be precipitated by the addition of common ſalt (See article *Mercury*), which cannot be done from a ſolution made by gold; and calomel, prepared in the common way, is nothing but a neutral marine ſalt, incorporated by trituration with ſome metallic mercury. The effect of heat to promote the ſolution of a metal in its entire form, is the more remarkable, when we conſider the ſolution of tin in aqua regia is effected in the oppoſite manner, where the metal is calcined by the ſmalleſt degree of heat, and rendered inſoluble.

Once a metal has been diſſolved in an acid, it may be thrown down from the ſolvent by the addition either of an alkaline ſalt, or of ſome other metal which poſſeſſes a ſtronger attraction to the menſtruum. But in the caſe of metallic precipitations, we meet with many anomalous facts, which it is not eaſy to reduce under any general law. A ſolution of green vitriol will precipitate gold from aqua regia; and, what is ſtill more extraordinary, a ſolution of tin in aqua regia will precipitate gold from aqua regia in form of a purple powder, provided the ſolutions be ſufficiently diluted with water. Both theſe facts, eſpecially the laſt, are moſt ſingularly remarkable; and, in a caſe ſo ſtrange, it ſeems more prudent to ſuſpend our judgment of the cauſe, than to adopt an opinion which may be inconſiderate and erroneous.

Although one metal is precipitated by the addition of another metal, the precipitation is not always occaſioned by the calx of the precipitant. The reaſon of this difference is obvious. One metal precipitates another by means of a double elective attraction, and gives a metallic precipitate; ſo that the conjoined action of the two attractions will operate more powerfully than when but one is employed, as in the caſe of one calx diſplacing another without any ſuch aſſiſtance. And it is for the ſame reaſon that the order of attraction of acids to metals, and to their calces, is not always the ſame; and whoever means to conſtitute a table of elective attractions with much accuracy, will do well to attend to the variation, as M. Bergman has done. M. Bergman has likewiſe endeavoured to employ the precipitation of one metal by another, as a means of eſtimating the proportional quantity of phlogiſton which each of them may contain. He diſſolves 100 parts of ſilver in nitrous acid, and employs different metals as precipitants. The 100 parts of ſilver were found to require, in order to precipitate it in a metallic ſtate,

Parts.		
135	of	mercury,
31	—	copper,
234	—	lead,
55	—	zinc,
74	—	biſmuth.

From theſe experiments he infers, that the phlogiſton contained in 100 parts of ſilver is equivalent to that contained in the abovementioned proportion of precipitants; and thus he computes the proportional quantity of phlogiſton in the different metals. If the mode of computation be juſt, we ſhould find all metals tally with each other, whatever ſtandard of compariſon be uſed. Thus, as the calculation by precipitating ſilver gives the proportion of phlogiſton in zinc to the proportion of the ſame principle in mercury, as 55 to 135, 55 parts of zinc ſhould precipitate 135 of mercury; but it requires a larger proportion, nearly 58. One hundred and ſeventy-four parts of biſmuth ſhould fall, according to M. Bergman's computation, by 55 parts of zinc, though they conſume about 85; a prodigious irregularity, from which we may ſuſpect that the method is by no means accurate. Indeed, if we conſider, that in order to make the ſucceſs complete, the acid menſtruum muſt be ſaturated with quantities of different metals, which contain equal portions of phlogiſton, we perceive that there is little chance this teſt will hold. As 135 parts of mercury are requiſite to furniſh phlogiſton to 100 parts of ſilver, the ſame quantity of acid muſt be ſaturated with 135 parts of mercury and 100 of ſilver, elſe many inconveniences will enſue. If we ſuppoſe that the precipitant metallic ſubſtance is richer in phlogiſton than the one to be precipitated, but that its calx has a leſs powerful attraction for the ſolvent, the conſequence neceſſarily muſt be, that when a ſufficient quantity is immerſed to furniſh phlogiſton to the whole of the diſſolved metal, only a portion of it will fall, correſpondent to that portion of the acid now ſaturated with the precipitant. The whole cannot fall, elſe part of the acid would be left unſaturated, which will not probably happen, and phlogiſton will eſcape in the ſolution, and not be accounted for in the computation. If a ſufficient quantity of the precipitant metallic ſubſtance be not ſoluble in the menſtruum, the inconvenience is ſtill more obvious, as the whole of the diſſolved metallic ſubſtance will not be ſaturated with phlogiſton; ſo that no juſt eſtimate can be obtained. This difficulty actually occurs in precipitations of ſilver by tin, where a portion of tin is only partially calcined, and diſturbs the accuracy of the reſult. There are ſome other objections which might be ſtated to this propoſal, if it were proper to dwell at greater length upon a ſubject of ſpeculation ſo little inveſtigated.

Metallic calces have all been ſuppoſed to reſemble the nature of an earth, and were commonly ſpoken of as ſuch until very lately, that M. Scheele diſcovered that the calx of arſenic might be reſolved into

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a pure acid. Since that time, ſeveral gentlemen have endeavoured to proſecute the ſubject upon the ſame principles; and ſome of them have had the good fortune to meet with radical acids, which were convertible into the regulus of a metal by proper treatment. The number of thoſe newly-diſcovered metallic acids is three; the acid of the ſiderum, which was mentioned as the cauſe of cold ſhortneſs in iron; the acid of the lapis ponderoſus; and the acid of molybdæna. But ſo little is yet known of the diſtinctive properties poſſeſſed by the metals which thoſe acids produce, that it will be ſufficient to announce the diſcovery of them here, and to obſerve, that they may all be formed into perfect metals, by means of the ſame treatment and additions, as the calx of arſenic.

The doctrine which believes in the ſimplicity of the metallic calces, whether they be of an acid or of an earthy nature, is exactly the converſe of M. Lavoiſier's theory, which ſuppoſes the metals to be ſimple ſubſtances, and their calces to be combinations of them with pure air. Whether the calces aſſume a ſaline or earthy appearance, this ſyſtem is alike applicable, as M. Lavoiſier alſo aſſerts, that all acids are chiefly compoſed of the ſame kind of air. According to this ſyſtem, a metallic regulus is not ſoluble in an acid from a deficiency of air in the acid, or from a greater attraction for the air by the acid, and not from the redundancy of phlogiſton; and is rendered ſoluble by impregnating the acid with more air, as happens in digeſting marine acid upon manganeſe. In the precipitation of one metal by another, the calx furniſhes the air to the metal, and is left deſtitute itſelf under a reguline form. When the ſolution of tin in aqua regia precipitates gold from aqua regia, the reaſon is obvious. The tin poſſeſſes a ſtrong attraction for pure air, which it receives from the gold, that received it from the acid; and thus by rubbing the gold and enriching itſelf, both metals become no longer ſoluble in their common menſtruum. So far is conſonant to common experience, that gold not ſufficiently calcined, or tin too much calcined, are neither of them capable of ſuſpenſion in aqua regia.

LECTURE XLII.

Genus 5. BITUMENS *.

THE bitumens are combuſtible, ſolid, ſoft, or fluid ſubſtances, of a ſtrong acrid aromatic ſmell, ſeeming to be much more compounded than the bodies of the mineral kingdom juſt now examined. They are found either forming layers in the heart of the earth, or dropping through rocks, or ſwimming upon the ſurface of waters. Their character is, they burn for the moſt part with flame, when they are heated with the contact of air, as the ſubſtances do which are formed by the organs of animals and vegetables, and to which we give the name of *oils*. Their analyſis is much leſs accurate than the analyſis of the earthy, ſaline, or metallic bodies; becauſe the action of fire alters them remarkably, and principles are extracted from them which react upon one another in proportion as they are volatiliſed. The bitumens have an analogy with vegetable and animal ſubſtances. By diſtillation they give over an odorous water or phlegm, more or leſs coloured and ſaline; an acid, frequently concrete; ſometimes ſome volatile alkali and oils; which, from being light at firſt, become thicker and more coloured as the diſtillation advances, and according to the force of the heat applied. After this analyſis, there remains a greater or leſs quantity of groſs, light, rare, brilliant, or compact charry matter, according to the different kinds of bitumens. This analyſis ſhows, that inflammable bodies have a vegetable or animal origin, as will be more clearly ſeen in the enumeration of their properties.

The bitumens ſuffer ſome alteration from light: when they are fluid, their colour deepens, and their ſmell is modified in tranſparent veſſels. The air thickens them by the ſucceſſive evaporation of their humidity, which flies off the more quickly the drier the air is. Their ſpiritus rector, or ſmell, diſſipates in the ſame proportion; and they are gradually converted from the ſtate of fluidity to tenacity and ſolidity; but a great number of years is requiſite for completing this alteration.

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* It ought to be recollected, that we divided the mineral combuſtible ſubſtances into five genera; which are, the diamond, inflammable gas, ſulpur, the metallic ſubſtances, and the bitumens.

Water in which the bitumens are boiled does not diſſolve them; but it takes up their ſpiritus rector, and emits the ſmell which is peculiar to them: hence it ſeems, that water has more affinity with their ſmelling principle than with the oily matter of the bitumen, and might perhaps thus deprive theſe bodies of all their odour.

The action of the ſaline-earthy matters upon the bitumens has not been examined. However, lime, and alſo the pure alkalis, ſeem capable of uniting with them, and of forming compounds ſoluble in water, which have got the name of *ſoaps*. Nor do we know the way in which the mineral acids act upon them; it is probable that they would diſſolve and put them into a ſoapy ſtate, as they do to the oils. Nor has the action of the neutral ſalts, inflammable gas, ſulphur, and the metallic bodies, been examined: in general, indeed, the chemical properties of theſe bodies are but very little known. This ſubject is entirely new, and experiments might produce perhaps uſeful reſults.

The naturaliſts have been much more buſied about the origin and formation of the bitumens, than the chemiſts about their analyſis. There are ſeveral opinions upon this point. Some think, that theſe combuſtible bodies belong properly to the mineral kingdom, and that they are to the minerals what the oils and reſins are to the organic ſubſtances. The analogy, which is ſomewhat agreeable to the imagination, does not agree with the facts; for nothing is known in the mineral kingdom which poſſeſſes the character of oils. For this reaſon, the opinion of thoſe who aſcribe the bitumens to vegetable ſubſtances buried in the heart of the earth, and altered by the action of the mineral acids, has been more generally adopted than the former. In fact, every thing proves that the bitumens originate from organic ſubſtances. In their neighbourhood a great deal of theſe ſubſtances is conſtantly found, whoſe form is diſtinguiſhable; beſides, they have themſelves the chemical characters of ſubſtances formed by life; and, in a certain degree, they may be imitated, by combining ſome oils with concentrated vitriolic acid. In the chemical hiſtory of the vegetable ſubſtances, we ſhall take notice, that the oil of vitriol, put in contact with eſſential oils, blackens, hardens, and gives them a ſtrong pungent odour, reſembling that of the bitumens. But are theſe bodies formed only by vegetables buried in the earth, as moſt naturaliſts have advanced, and do animals contribute nothing? The great quantity of bitumens which exiſts in the heart of the earth, compared with the little wood found in their neighbourhood, and in particular the ſmall quantity of oily ſubſtances which theſe vegetables contain, ſeem to oppoſe the opinion that the origin of bitumens is entirely owing to the individuals of the vegetable kingdom: on the contrary, the abundance of theſe combuſtible ſubſtances, in places where only traces of vegetables are found, and the almoſt conſtant appearance of the carcaſes of animals heaped above the bitumens, ſhould lead us to ſuppoſe, that the organic ſubſtances have greatly, and perhaps even more than vegetables, contributed to their formation. Let us obſerve alſo, that the ſucceſſive layers of ſome bitumens which are found in continued maſſes in the heart of the globe, announce that theſe bodies have been ſlowly depoſited by the waters, and that their formation correſponds with the epoch when the immenſe heaps of ſhells and other marine ſubſtances were formed by the ſea. They have therefore been in a fluid ſtate, and blackened through time by the action of ſaline bodies, or of other agents, which the heart of the earth contains in great quantity. Such is the opinion of M. Parmentier, member of the College of Pharmacy, which he has given upon the origin of the charcoal of earth, in a memoir which he read at the opening of the courſe of this company. The oils and the fats of marine animals appear, then, to be materials which nature uſes for the formation of certain bitumens, whilſt the origin of others is manifeſtly vegetable, and is owing to the reſins or eſſential oils buried and altered in the earth.

The number of bitumens is very great. The naturaliſts have made ſeveral genera of them. Chemically conſidered, we look upon them as ſpecies; becauſe in fact they have all the ſame characters relatively to their chemical properties. Some are liquid, others are of a ſoft conſiſtence: ſome are ſolid; and among theſe laſt ſome are hard, and ſuſceptible of a poliſh; others are friable. We diſtinguiſh ſix very diſtinct ſpecies of them, which comprehend a great quantity of varieties, which we ſhall point out. Theſe ſix ſpecies, whoſe hiſtory we are going to give, are, amber, aſphaltes, bitumen of Judea, jet, charcoal of earth, ambergris, and petroleum.

Species 1. *Amber.*

Amber, called *yellow amber* or *karabé*, is the fineſt of all the bitumens in its external characters: it is in irregular pieces, of a yellow or brown colour, tranſparent or opaque, formed of layers or ſcales. It is ſuſceptible of a very pretty poliſh. When it is rubbed ſome time, it becomes electrical, and capable of attracting ſtraws. The ancients, who knew this property, gave ſuccinum the name of *electrum*, from whence came *electricity*.

This bitumen is of a very hard conſiſtence, approaching to that of certain ſtones; which circumſtance induced ſome authors, and in particular Hartman a naturaliſt, who lived about the end of the laſt century, to rank them among the precious ſtones. However, it is friable and brittle. When it is pounded, it emits a very agreeable odour. In its heart inſects are often found very well preſerved and very diſtinguiſhable; which proves that it has been liquid, and that in this ſtate it enveloped the ſubſtances found in it.

Amber is for the moſt part buried more or leſs deeply: it is found under coloured ſands, in ſmall incoherent pieces, and diſperſed in beds of pyritous earth; above it, wood charged with a blackiſh bituminous matter is found: hence it is believed, that it is formed of a reſinous ſubſtance, which has been altered by the vitriolic acid of the pyrites. It ſwims alſo at the ſides of the ſea. It is collected on the ſides of the Baltic ſea in Ducal Pruſſia. The mountains of Provence near the city of Siſteron, the marquiſate of Ancona, and the duchy of Spoletto in Italy, Sicily, Poland, Sweden, and ſeveral other countries, produce it. The colour, the texture, the tranſparency, and opacity of this bitumen, have diſtinguiſhed a very great number of varieties. According to Wallerius, they may be reduced to the following:

1. White tranſparent ſuccinum.
2. Tranſparent ſuccinum, of a pale yellow.
3. Tranſparent ſuccinum, a citron yellow.
4. Tranſparent ſuccinum, of a golden yellow; chryſelectrum of the ancients.
5. Tranſparent ſuccinum, of a deep red.
6. White opaque ſuccinum; leucelectrum.
7. Yellow opaque ſuccinum.
8. Brown opaque ſuccinum.
9. Succinum, coloured green, or blue by foreign matters.
10. Veined ſuccinum.

There might ſtill be a greater number of varieties from its internal appearances. But we ſhould be cautious with regard to the value which we put upon ſpecimens of it, which are remarkable for their ſize, tranſparency, and the well-preſerved inſects which they contain internally; ſince there is a poſſibility of deception, ſeveral perſons poſſeſſing the art of giving it tranſparency, of colouring it at pleaſure, and of ſoftening it ſo as to introduce foreign ſubſtances.

Wallerius takes notice, that the golden-coloured amber always owes its tranſparency to nature, and that artificial tranſparency is always mixed with a pale colour.

Although it be very probable that this bitumen owes its origin to vegetable reſinous matters, ſeveral naturaliſts have had different opinions upon its formation. Some have conſidered it as the hardened urine of certain quadrupeds; others as an earthy juice which the ſea has carried away, and which, carried by the waters upon the ſhore, is dried and hardened by the rays of the ſun. This claſs of naturaliſts conſiders it as a particular mineral juice. Such was the opinion of an ancient naturaliſt called *Philemon*, and mentioned by Pliny. George Agricola afterwards revived it. Frederic Hoffman imagined it to be formed of a light oil, ſeparated from the bituminous woods by heat, and made thick by the vitriolic acid. This opinion of Hoffman cannot be adopted; for we do not underſtand how an oil, ſeparated in the interior parts of the earth, could contain animals which live only at its ſurface. It is more than probable, that amber is owing to a reſinous juice which firſt flows fluid from ſome tree: this juice, buried more or leſs deep in the earth, by the revolutions which the globe has ſuffered, is hardened, and impregnated with mineral and ſaline vapours, which circulate through it. There is not even an appearance that it has been altered by concentrated acids; for experiment ſhows us, that the action of the acids would have blackened and converted it into a charry matter. Pliny thought, that amber was nothing but the reſin of the pine, hardened by the coolneſs of autumn. Some authors have thought, that it was produced from a kind of reſin, improperly called *gum-copal*, which had for ſome time continued in the earth. But whatever analogy there may ſeem to be betwixt theſe two ſubſtances, we cannot abſolutely ſpecify the kind of vegetable matters to which the amber belonged.

Amber, expoſed to the fire, does not liquefy without a very ſtrong heat; it ſoftens, and bubbles up greatly. When it is heated with the contact of air, it kindles, and emits a very thick and very fragrant fume. Its flame is yellowiſh, variegated green and blue. A black ſhining charcoal is left after combuſtion, which by incineration yields a very ſmall quantity of brown earth. M. Bourdelin, in his Memoir upon Amber, Acad. 1742, obtained only eighteen grains of this earth by burning two pounds of amber in a matraſs. A half pound of the ſame bitumen, burnt and calcined in a crucible, yielded him, in a ſecond operation, twelve grains of an earthy reſiduum, from which he procured iron by means of a magnetic bar.

If amber is diſtilled in a retort and with a graduated fire, a red phlegm at firſt comes over, which is manifeſtly acid. This acid ſpirit retains the ſtrong odour of the ſuccinum; then a volatile acid ſalt, which cryſtalliſes in ſmall white or yellowiſh needles in the neck of the retort; next, a white and light oil of a very vivid colour. This oil gradually turns coloured as the fire turns ſtronger; and ends in a brown blackiſh, thick, viſcous, matter, like empyreumatic oils. During the paſſage of theſe two oils, a certain quantity of volatile ſalt ſublimes, more or leſs coloured. After this operation, there remains in the retort a black maſs, moulded upon the bottom of the retort, brittle, and reſembling the bitumen of Judea: George Agricola, near three centuries ago, made this obſervation upon diſtilled amber. If the operation is conducted with a gentle and well-regulated fire, and if the amber is in great quantity, all theſe products may be obtained ſeparately by changing the receiver. Generally they are received in the ſame veſſel, and then rectified with a gentle heat. The ſpirit is ſomewhat diſcoloured in this rectification. The oil, which comes over black at the end of the operation, on account of its carrying along with it a charry matter, and of the reaction of the acid upon its principles, may be rendered very white and light by ſeveral ſucceſſive diſtillations. M. Rouelle has given a very good proceſs for obtaining it in this ſtate by one operation. For this purpoſe, this oil is to be put along with ſome water into a glaſs alembic, and diſtilled with the heat of boiling water; the moſt pure and the only portion which is volatiliſed with this degree of heat, on account of its lightneſs, paſſes over with the water above which it is collected. If we want to preſerve it in this ſtate, it muſt be kept in veſſels of free-ſtone; for in glaſs veſſels, the rays of light penetrating through them, in no long time give it a yellow and even brown colour.

This analyſis demonſtrates, that amber is formed of a great quantity of oil, rendered concrete by an acid. It alſo contains a very ſmall quantity of earth, whoſe nature has not been examined, and ſome atoms of iron.

Oil of amber ſeems to approach to eſſential oils; it poſſeſſes their volatility and ſmell: it is very inflammable: it ſeems capable of forming ſoaps with the alkalis.

The volatile ſalt of amber was for ſome time conſidered as an alkaline ſalt. Glaſer, Lefevre, Charas, and Jean Maurice Hoffman profeſſor at Altdorf, were of this opinion. Barchuſen, and Boulduc the father, are the two firſt chemiſts who, in the laſt century, diſcovered the acid nature of this ſalt. Since their time, all the chemiſts have adopted that opinion, but have not agreed about the nature of this acid. Freferic Hoffman, becauſe amber is found in Pruſſia in layers filled with pyrites, imagined that its ſalt is formed of vitriolic acid. Neuman ſeems to be of the ſame opinion. M. Bourdelin, in the above-mentioned Memoir, mentions ſeveral experiments which he made, with a view to determine the nature of this ſalt. He obſerves firſt, that the ſal ſuccini, obtained by diſtillation from this bitumen, however white and pure it is, contains always an oily matter: it is without doubt to this ſubſtance that it owes its ſmell and the kind of combuſtibility which it poſſeſſes and exhibits when it is thrown upon burning coals. Several methods have been tried to rid it of this ſubſtance. When we come to examine the nature and properties of ardent ſpirits, we ſhall ſee that this fluid is unfit for the purpoſe.

The fixed alkali, digeſted upon amber with a view to carry off the fat and oily matter, and to obtain the ſalt in a ſimple ſtate, has no better ſucceſs; it diſſolved only a little bitumen, and acquired a lixivial ſaline taſte like marine ſalt.

M. Bourdelin could not find a better proceſs for the union of the acid of amber in its pure ſtate, deprived of all oily matter, with the fixed alkali, than to detonate a mixture of two parts of nitre with one of this bitumen. He waſhed the reſiduum of this operation with diſtilled water. This ley conſiſted of a ſalt of amber: it precipitated the ſolution of ſilver in white ſcales; and that of mercury in the ſame colour. Several other metallic ſolutions were likewiſe decompoſed; but M. Bourdelin conſidered theſe two facts as inconcluſive. They ſeemed to him to ſhow, that the acid of amber was the ſame with marine acid, the ſame phenomenon being preſented by this laſt with the nitrous ſolutions of mercury and ſilver. The ley of the reſiduum, evaporated with the air, yielded a mucilaginous matter; in the middle of which elongated ſquare cryſtals were gradually depoſited, whoſe form, ſaline taſte, decrepitation upon burning coals, and in particular the conſiderable effervеſcence and ſmell of marine acid which they raiſed by the affuſion of oil of vitriol, ſhowed him, that the ſpirit of ſalt was here united with the baſe of the nitre. In ſpite of this analyſis, which is very accurate, conſidering the time in which M. Bourdelin wrought, the chemiſts, who ſince him have examined the ſal ſuccini, have found it not analagous to the marine acid, and have diſcovered in it all the characters of an oily vegetable acid.

The inveſtigation of the chemical properties of this bitumen has not been carried farther. Even the way in which the acids act upon it is not known. Frederic Hoffman aſſerts, that it may be entirely diſſolved in a cauſtic fixed alkaline ley, and in the acid of vitriol. It is known alſo, that the eſſential oil of amber can unite with the volatile cauſtic alkali; and, by ſimple mixture and agitation, form a kind of liquid ſoap of a milky whiteneſs and penetrating ſmell, which is known in pharmacy by the name of *eau de luce:* laſtly, that this ſame oil diſſolves ſulphur with the heat of a ſand-bath, and conſtitutes a medicine called *balſamum ſulphuris ſuccinatum.*

Amber is employed in medicine as an antiſpaſmodic: it is recommended in hyſterical and hypochondriacal affections, amenorrhœa, gonorrhœa, fluor albus, &c. It is employed in ſubſtance, after waſhing with hot water and porphyrization. It is uſed in ſtrengthening and reſolving fumigations, by putting it powdered upon a hot-brick, and directing the fume which it emits upon the part to be ſubjected to its action.

The volatile ſpirit and the ſalt of amber are conſidered as expectorants, cordials, and antiſeptics: they are likewiſe uſed as powerful diuretics. The oil of amber is employed externally and internally for the ſame purpoſes as amber itſelf: it is preſcribed in leſs doſes, on account of its greater activity. Balſamum ſulphuris ſuccinatum, which is given to the quantity of ſome few drops in proper drinks, or mixed with other ſubſtances to form pills, has been ſucceſsfully uſed in humoural and pituitous affections of the breaſt, kidneys, &c. With the ſpirit of amber and opium a ſyrup is made, called *ſpirit of karabé*, which is uſed ſucceſsfully as a calming anodyne and antiſpaſmodic medicine. L'eau de luce, which is prepared by pouring ſome drops of oil of amber into a veſſel of volatile cauſtic alkali, and agitating this mixture till it has acquired a white milky colour, has been long in uſe as a very active ſtimulant in aſphyxies: it is held near the noſtrils, and ſtimulates the nerves; and by the agitation which it excites, it reproduces the motion of the fluids, and recovers the patient.

The fineſt pieces of amber are cut and turned, to make vaſes, heads of canes, collars, bracelets, ſnuff-boxes. Theſe kinds of trinkets were no longer to be found after diamonds and ſtones came into uſe; but they are ſent to Perſia, China, and ſeveral other nations, which eſtimate them ſtill as great rarieties. Wallerius ſays, that the moſt tranſparent bits may be employed for microſcopes, burning-glaſſes, priſms, &c. It is ſaid that the King of Pruſſia has a burning-glaſs of amber a foot in diameter; and that there is, in the cabinets of the Duke of Florence, a column of amber ſix feet high, and a very beautiful luſtre. Two pieces of this bitumen may be united, by applying them to one another, after being wet with oil of tartar and heated.

Species 2. *Aſphaltum.*

ASPHALTUM, or Bitumen of Judea, called alſo *gum of funerals*, *karabé of Sodom*, *mountain pitch*, *mummy's balſam*, is a black, heavy, ſolid, very brilliant, bitumen. It is eaſily broken, and its fracture is vitreous. A ſmall lamina of it appears red when placed between the eye and the light. Aſphaltum has no ſmell when it is cold: when it is rubbed it acquires a lightneſs. It is found upon the waters of the lake Aſphaltides or Dead Sea in Judea, near which the ancient cities of Sodom and Gomorrha were ſituated. The inhabitants, diſturbed with the ſmell of this bitumen amaſſed upon the waters, and encouraged by the profit which is got from it, collect it with care. Lemery, in his Dictionary of Drugs, ſays, that the aſphaltum is diſgorged like a liquid pitch from the earth covered by the Dead Sea, and that, raiſed to the ſurface of the water, it is there condenſed by the heat of the ſun, and by the action of the ſalt, which theſe waters contain in great quantity. It is found alſo in ſeveral lakes of China.

Aſphaltum of commerce is extracted, according to M. Valmont de Bomare, from mines of Daunemore, and particularly in the principality of Neufchatel and of Wallengin. It is of two colours, according to this naturaliſt; blackiſh, greyiſh or fallow: but this aſphaltum is not nearly pure; and it ſeems to be only an earth hardened and penetrated by the bitumen.

Naturaliſts are divided upon the origin of aſphaltum, as they are upon that of all the bitumens. Some ſuppoſe it a mineral production, formed by the union of an acid with a greaſy ſubſtance in the heart of the earth: others conſider it as a vegetable reſinous ſubſtance, buried under earth, and altered by the mineral acids. The moſt general and moſt probable opinion is, that it is of the ſame origin with amber, and that it is formed by this laſt bitumen, which has undergone the action of a ſubterraneous fire.

Aſphaltum, expoſed to the fire, liquefies, bubbles up, and burns with a flame and thick ſmoke of a ſtrong acrid diſagreeable ſmell. By diſtillation, it gives over a coloured oil like petroleum. This natural product has not been chemically examined.

Aſphaltum is employed as a covering to ſhips by the Arabs and Indians. It enters into the compoſition of black China varniſhes, and into the artificial fires which burn upon water. The Egyptians uſe to embalm their bodies with it; but for this purpoſe it was uſed only by the poorer ſort, who could not procure more precious antiſeptics. Wallerius ſays, that merchants prepare a kind of aſphaltes with thickened pitch, or by mixing and fuſing this with a certain quantity of true balſam of Judea: but this fraud may be detected by means of ſpirit of wine, which entirely diſſolves the pitch, and aſſumes only a yellow colour with aſphaltum.

Spe-

Species 3. *Jet.*

Jet, called by the Latins *gagas*, *black amber* by Pliny, *pangitis* by Strabo, is a black bitumen, compact, and hard like ſome ſtones; brilliant and vitreous in its fracture, and ſuſceptible of a fine poliſh. When it is rubbed for ſome time, it attracts light bodies, and appears electrical like ſuccinum. It has no ſmell: when heated, it acquires one nearly reſembling that of bitumen of Judea.

Jet is found in France in Provence, in the county of Foix: there is alſo a quarry of it which is wrought at Beleſtat in the Pyrenees. It is found alſo in Sweden, in Germany, and Ireland. The quarries of jet are diſpoſed in beds; they contain pyrites, juſt like pit-coal, and the moſt part of the bitumens.

This bitumen ſoftens and fuſes when ſtrongly heated: it emits a fetid odour upon burning. Some oil is extracted by diſtillation.

Among the different opinions upon the formation of jet, the moſt probable is, that it is aſphaltum made hard by the lapſe of time. This was adopted by the learned Wallerius.

Jet is employed to make mourning trinkets. Wirtemberg is the place where it is wrought upon. It makes buttons, bracelets, boxes.

Species 4. *Foſſile Coal.*

The name of *foſſile coal*, *pit-coal*, *lithantrax*, *earth-coal*, *ſtone-coal*, is given to a black, laminous, ſhining or dull ſubſtance, which breaks eaſily, but has not properly the conſiſtence and purity of the bitumens deſcribed.

This bitumen has received its name from its combuſtible property, and the uſe for which it is employed in ſeveral countries. It is found in the heart of the earth, below ſtones more or leſs hard, and aluminous or pyritous maſſes. Theſe laſt conſtantly bear the mark of ſeveral vegetables, which for the moſt part are exotic, according to the obſervation of M. Bernard de Jeſſieu. Pit-coal is at a greater or leſs depth in the earth. It is diſpoſed always in horizontal or inclined layers: the latter diſpoſition is the moſt frequent. The layers which compoſe it differ in thickneſs, conſiſtence, colour, weight. More or leſs extenſive layers of ſhells and foſſile madrepores are often found above this bitumen; which have made ſome moderns believe, and particularly M. Parmentier, that pit-coal had been formed in the ſea by the depoſition and alteration of the oily or fat matters of marine animals. Quarries of pit-coal are wrought, like mines, by digging pits, and forming galleries; and the coal is detached by means of pick-axes. The workmen are often in the danger of loſing their lives by the choak-damp. This ſubſtance is called *touſſe* or *pouſſe* by the workmen. It extinguiſhes candles, and ſeems to be fixed air. In theſe pits a kind of inflammable gas is alſo produced, very deleterious, which produces ſometimes dangerous exploſions.

Pit-coal ſeems to be very copious in the earth. It is found in Scotland, England, Ireland, Hainault, the countries of Liege, Sweden, Bohemia, Saxony, &c. Several countries of France furniſh a great quantity of it; and particularly Bourgogne, Lyonnois, Forez, Auvergne, Normandy, &c.

Pit-coal is diſtingniſhed into earth-coal and ſtone-coal, according to its hardneſs or friability; but the manner in which it burns, and the phenomena which it preſents in combuſtion, furniſh characters of very great importance to diſtinguiſh the different ſorts. Upon this view Wallerius diſtinguiſhes three ſorts.

1. Scaly earth-coal, which remains black after combuſtion.

2. Compact and luminous earth-coal, which after combuſtion yields a ſpongy matter reſembling ſcoriæ.

3. Earth-coal, fibrous like wood, which is reduced into aſhes by combuſtion.

This bitumen, heated in contact with a body in combuſtion and with the air, kindles the more ſlowly and difficultly as it is more weighty and compact: once it is kindled, it emits a briſk and very durable heat, and is a long time burning before conſumption: it may alſo be extinguiſhed, and ſerve ſeveral times for a new combuſtion. Its inflammable matter appears very denſe, and as if fixed to another incombuſtible ſubſtance, which retards its deſtruction. Upon burning, it exhales a particular ſtrong ſmell, but it is nowiſe ſulphureous when the earth-coal is very pure and contains no pyrites. The combuſtion of this bitumen appears to be very analogous to that of organic ſubſtances, in this, that it is ſuſceptible of being ſtopped and of being divided into two diſtinct periods. The combuſtible, oily, and moſt volatile part which the earth-coal contains, is diſſipated and ſet on fire by the firſt application of heat; and if, when all this principle is diſſipated, the combuſtion is ſtopped, the bitumen retains only the moſt fixed and leaſt inflammable part of its oil, reduced to a true charry ſtate, and combined with an earthy baſe. This is the proceſs the Engliſh employ for the preparation of their coaks, which is only earth-coal deprived of its oily fluid part by the action of the fire. It is very eaſily ſeen what paſſes in this experiment, by heating it in cloſe veſſels in a diſtilling apparatus. There is obtained an alkaline phlegm, ſome concrete volatile alkali, an oil which deepens in colour, and becomes more weighty as the diſtillation advances. At the ſame time, a great quantity of an elaſtic inflammable fluid comes over, which is conſidered as an oil in vapour, but which might be rather a particular inflammable gas. A ſcorified matter remains in the retort, charry, and ſtill capable of being kindled: this is the coaks of the Engliſh. If the action of the fire upon the pure earth-coal is carefully attended to, we obſerve, that it undergoes an evident ſoftening, and ſeemingly a ſemifuſion: now it is known, ſince this ſtate injures the fuſion of ores, that it is eſſential to deprive earth-coal of this property. This has been done by carrying off this ſoftening principle, that is, the oil which it contains in great abundance, and reducing it to a ſtate analogous to that of the coal of vegetables. Let us not forget to obſerve, that the volatile alkali, which is formed in very great quantity by the earth-coal, favours the opinion which we have given upon its animal origin: ſince, as we ſhall take notice elſewhere, the bodies which belong to the animal kingdom, yield always this ſalt in their diſtillation.

Earth-coal is ſingularly uſeful in countries where there is no wood. It is uſed as fire materials, and without the fear of any danger, which ſome perſons have aſcribed to its uſe: the ſulphureous vapour which it has been ſaid to emit, ought not to be regarded as any objection to it, ſince the moſt accurate analyſis has convinced all chemiſts, that when earth-coal is pure, it contains not an atom of ſulphur. Hence we ſee how falſe and deceiving the pretenſions of ſome illiterate men are, who boaſt of proceſſes to deprive this bitumen of ſulphur. Another conſideration which ought particularly to induce the working of earth-coal, particularly in France, is, that the working of ores conſumes enormous quantities of charcoal of wood, and it is to be feared that the wood may in time fail: it is particularly in theſe kinds of works that induſtry ſhould endeavour to find out the earth-coal, as the Engliſh have done long ago *.

* Earth-coal being become an object of great utility, deſerving all the attention of philoſophers, on account of the different uſes for which it may be ſucceſsfully employed; it is proper to conſult what authors have ſaid about it, who have publiſhed treatiſes or particular memoirs upon the ſubject. Such are M. de Genſſane, M. Venel, Meſſrs Jars, and particularly M. Morand, who has undertaken and executed a complete and very extenſive work upon earth-coal.

The great abundance of pit-coal found in the iſland of Great Britain conſtitutes a chief part of the riches of the country; as coal affords a very powerful ſpecies of fuel in all the arts in which heat is employed, and as it can, by the improved modes of working, be ap-

plied

Species 5. *Ambergris.*

AMBERGRIS is a concrete ſubſtance, of a ſoft and tenacious conſiſtence like wax, grey-coloured, ſtained yellow or black, of a ſtrong agreeable ſmell when it is heated or rubbed. It is in irregular, ſometimes round maſſes,

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plied to the manufacture of iron, and to other purpoſes for which it was formerly ſuppoſed to be unfit. When coal is deprived of the more fluid matters by uſtulation, a ſpecies of charcoal or cinders remains, which is known by the name of *coaks*; and the coal in this ſtate is capable of exciting the moſt intenſe heat. In the former method of converting coal into coaks, the volatile matters were diſſipated in pure loſs; but more recently the workmen have learned to collect what is expelled by the heat, as it is found to yield a moſt excellent kind of pitch, admirably calculated to ſerve all the uſes of common pitch, and to be in ſome inſtances preferable to what is obtained from wood. The pitch comes over in the form of a volatile vapour, which are made to condenſe in the cold by means of a large quantity of cold water and of cold air; ſo that the reſervoir or refrigeratory muſt be of a capacious ſize, and placed at a diſtance from the diſtillation oven, beyond the reach of the fire. I have uſed the term *diſtillation*, though it is not perhaps proper in this caſe, ſince no external heat is employed to ſeparate the component parts of the ſubject from one another. The ovens are ſo contrived to admit an under ſupply of air, ſo that the coals, after they are kindled, ſpontaneouſly decompoſe themſelves by a ſlow incomplete ſpecies of combuſtion, which does not deſtroy the ingredients. The reſiduum, left in the oven proves moſt excellent cinders or coaks. The product collected in the refrigeratory is in part a volatile alkaline ſpirit, but chiefly a viſcid bituminous ſubſtance, capable of being inſpiſſated into a more ſolid conſiſtence, and of affording pitch with ſomewhat of an offenſive ſmell; which is rather of an advantage, as it may tend to prevent the worms of warm climates from penetrating into the bottoms of ſhips; a calamity much dreaded by all ſeamen.

The legiſlature of Great Britain has thought proper to eſtabliſh a difference in the rate of duty payable by culm and other ſpecies of ſmall coal, carried coaſtwiſe, without ſpecifically marking the circumſtance in which their diſtinction conſiſts. In order to underſtand what this diſtinction ought to be, it is neceſſary to remark, that ſome kinds of coals in burning begin to melt, and ſo far come into a liquid ſtate, that the ſeparate pieces run together and unite by the adheſion of their ſurfaces. Such coals are called *caking coals*; and in them maſſes, formed by layers of different natures, and more or leſs thick, according as a greater number of them is united. Pieces of it have been ſeen weighing more than 200 lb. This ſubſtance has been manifeſtly liquid; and it has enveloped ſeveral ſtrange ſubſtances which are found in it; ſuch as heads of birds, feathers, bones of fiſhes, and other marine bodies. It is found floating upon the waters of the ſea about the Molucca iſlands, Madagaſcar, Sumatra, the coaſts of Coromandel.

Naturaliſts make ſeveral varieties of amber. Wallerius ſtates the ſix following.

1. Ambergris, ſtained yellow,
2. ——— ſtained black.

   Theſe two varieties are the moſt deſired and moſt precious.

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them it ſeems immaterial of what ſize the pieces be, ſince the ſmalleſt atoms will by fuſion coaleſce into one conſolidated maſs; ſo that the refuſe or droſs will furniſh a fuel fit for all the œconomical purpoſes of life. Other coals do not fuſe, unite, and cake by the application of heat, but retain this original form, and keep in detached pieces in the midſt of the fire. The ſmall of this coal cannot therefore be applied to domeſtic uſe; becauſe when in powder the coal-duſt inſinuates itſelf between the crevices, prevents the circulation of air, and choaks up and extinguiſhes the fire as completely as a parcel of incombuſtible ſand. It is the fragments and duſt of this coal which conſtitues culm, and which is only applicable to burn limeſtone, and make bricks; two very valuable articles in rural œconomy. I think that, after what has been ſaid upon the nature of coal, it will be an eaſy matter for any perſon to diſtinguiſh culm from the ſmall of caking coal. He has only to try whether or not he can make a fire of it in a common grate, without the addition of other fuel: if he be able, it is good coal; if not, it is culm. Or ſhould this trial be thought unſatisfactory, though it is in reality the beſt, let him put ſome upon an ignited iron ſhovel, to try whether it melts and runs together; or elſe let him ſend it to a cinder-baker, and if he can make cinders from it, he may ſafely pronounce the ſpecimen excellent coal. There never was any difficulty on the ſubject, and there would be no trouble in collecting the tax, were it not for the inſuperable ignorance and love of oppreſſion, which ſo often pervades the underling officers of the revenue.

3. White amber, of one colour only.
4. Yellow ——
5. Brown ——
6. Black ——

Theſe two laſt are got from whales, and are diſtinguiſhed by a diſagreeable animal ſmell. It is to be obſerved, that theſe varieties depend only upon the mixture of ſome ſtrange ſubſtances.

The origin of amber is much diſputed. Some look upon it as a kind of petrole which flows from rocks, and thickens by the ſun and the action of ſalted water: others conſider it as an animal product; and among theſe, ſome aſcribe it to the excrements of birds who live upon odoriferous herbs; others to the filth voided by ſea-calves, crocodiles, &c. Several have imagined that ambergris is formed by the whales, in the ſtomach of which it is often found. Pomet and Lemery have ſuppoſed that it was a mixture of wax and honey baked in the ſun, and altered by the ſea-water. M. Formey, who has adopted this opinion, has ſupported it with an experiment; which conſiſts in digeſting a mixture of wax and honey. He ſays that a product is yielded of a ſweet ſmell, very analogous to that of amber. Laſtly, ſome Engliſh authors look upon ambergris to be an animal juice, depoſited in bags placed near the origin of the genital organ of the male whale; and ſeveral others imagine that it is formed in the veſica urinaria of this fiſh. If this opinion were demonſtrated, ambergris would be very far from being a bitumen, and it ſhould be ranked in the claſs of reſinous animal juices, ſuch as muſk and civet. Notwithſtanding, this ſubſtance, analyſed by Meſſrs Geoffroy and Neuman, yielded them the ſame principles as the bitumens; that is to ſay, an acid ſpirit, a concrete acid ſalt, ſome oil, and a charry reſiduum; which induced them to rank it among theſe bodies.

Ambergris is an antiſpaſmodic, a ſtomachic, and cor-

dial.

dial. It is employed in proper drinks to the quantity of ſome grains; or it is mixed with other ſubſtances to form pills. Phyſicians make no extenſive uſe of it, becauſe they have obſerved, that the odorous principle, in which alone the virtues of this medicine conſiſt, is often too active, too penetrating, and injurious. Several perſons cannot indure its ſmell without ſuffering all the affections peculiar to irritations of the nerves: it ought therefore to be adminiſtered with great moderation. It is conſidered alſo as a powerful aphrodiſiac.

The greateſt uſe of ambergris is to furniſh a perfume to the toilette; it is generally mixed with muſk, which ſo attenuates its ſmell, as to render it ſweeter and more ſupportable; ſtill it is not agreeable to every body.

As ambergris is very dear, it is counterfeited and mixed with different ſubſtances. The true is diſtinguiſhable by the following characters: It is ſcaly, of a ſweet ſmell, inſipid; it fuſes without giving bubbles or ſcum when it is expoſed to the flame of a candle in a ſilver ſpoon; it ſwims above water; it does not ſtick to hot iron. That which does not exhibit all theſe properties, is alloyed and impure.

Species 6. *Petroleum.*

THE name of *petroleum* has been given to a liquid bituminous ſubſtance which runs between the ſtones upon rocks. This ſort of oil differs in its lightneſs, ſmell, conſiſtence, and inflammability. Authors have diſtinguiſhed a great number of varieties. They have given the name of *naphtha* to the lighteſt, moſt tranſparent, and moſt inflammable petroleum; that of *petroleum*, to a liquid ſomewhat thick bitumen of a deep brown colour; and laſtly, that of *mineral pitch* to a black bitumen, thick, moderately liquid, tenacious and adheſive to the fingers.

The varieties deſcribed by Wallerius and ſeveral other naturaliſts are theſe.

1. Naphtha, white.
2. ———-- red.
3. ———-- green or deep.
4. Petroleum, mixed with earth.
5. ————- dropping through ſtones.
6. ————- ſwimming upon waters.
7. Mineral pitch or maltha,
8. Piſſaphaltes. It is of a middle conſiſtence betwixt that of ordinary petroleum and aſphaltes or Jews pitch.

Different naphthas are formed in Italy in the duchy of Modena, on mount Ciaro, twelve leagues from Plaiſance. Kempfer relates, in his Amœnitates Exoticæ, that it is collected in great quantity in ſeveral places of Perſia. Petroleum runs in Sicily and in ſeveral places of Italy: in France, in the village of Gabian in Languedoc; in Alſace; at Neufchatel in Switzerland; in Scotland, &c. The piſſaphaltes and mineral pitch were formerly got from Babylon, where it was uſed inſtead of mortar to the walls; from Raguſa in Greece; and from the pond of Samoſate, capital of Comagene in Syria. To day they are got from the principality of Neufchatel and Wallengen; from the wells of Pege, one league from Clermont-Ferrand in Auvergne; and from ſeveral other places *.

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* The vapour of naphtha, which iſſues through crevices of the earth, is ſuppoſed to be the cauſe of the flame which is ſometimes ſeen on the waters of fountains.

There are many fountains where the vapour on the ſurface will take fire at the approach of a lighted candle. But there is a very noted fountain of this kind at Chittagon in the Eaſt Indies, which burſts out into flame of its own accord, whenever it has been extinguiſhed by any accident. The credulous inhabitants of the country conſecrated the ſpot to a favourite deity, and appointed a ſet of prieſts to watch over the waters of the fountain: But ſome European travellers, ſuſpecting the whole to be a pious fraud contrived to impoſe upon the credulity of the people, pulled down the wall to ſatisfy their curioſity, and found that the vapour actually kindled ſpontaneouſly whenever it was put out. I had this anecdote from a gentleman who was preſent at the time.

With regard to the different varieties mentioned, it muſt be obſerved, that they all ſeem to have the ſame origin, and that they differ from one another only in ſome particular modification. Moſt naturaliſts and chemiſts aſcribe their formation to the decompoſition of the ſolid bitumens by the operation of ſubterraneous fire. They obſerve, that the naphtha appeared to be the lighteſt oil, which the fire diſengages firſt; and that what follows, acquiring colour and conſiſtence, forms the different ſorts of petrolea; and that theſe laſt, united with ſome earthy ſubſtances, or altered by the acids, aſſume the characters of *mineral pitch* or of *piſſaphaltes*. For the ſupport of their opinion, they have a very exact compariſon with the phenomena which the diſtillation of amber preſents; and which in fact furniſhes a kind of naphtha, and a petroleum more or leſs brown, according to the degree of heat and the length of the operation. Laſtly, they obſerve, that nature preſents frequently all kinds of petrolea in the ſame place, from the lighteſt naphtha to mineral pitch. Such are the fluid bitumens got from mount Feſtin in the duchy of Modena. Although this opinion be very probable, ſome authors think that petroleum is a mineral oily combination, formed of the vitriolic acid and ſome fat matter.

The chemical properties of petroleum have not yet been examined: it is known only that naphtha is very volatile, and ſo combuſtible, as to take fire when in the neighbourhood of any ſubſtance in combuſtion: its volatility ſeems to be the cauſe of attracting the flame. An acid phlegm is procured from brown petroleum, and an oil, which at firſt reſembles naphtha, and becomes more coloured as the diſtillation advances. A thick matter like piſſaphaltum remains, which may be rendered dry and brittle like aſphaltum, and reduced entirely to a charry ſtate by a more active fire.

The different kinds of petroleum are employed for different uſes in the countries where they abound.

Kempfer tells us, that in Perſia it is uſed for giving light in lamps furniſhed with wicks. It may alſo be made uſe of as fuel. For this purpoſe, M. Lehman tells us, that ſome naphtha is poured upon ſome handfuls of earth, which are ſet fire to with a piece of paper; it inſtantly takes fire with activity, but it emits a very copious thick fume, which attaches itſelf to all bodies, and has a very diſagreeable odour. Petroleum is alſo ſuppoſed to enter into the compoſition of wild-fire. Thick petroleum is alſo employed to make a very hard and durable mortar. By the decoction of piſſaphaltum in water, an oil is got from this bitumen which is uſed to ſecure veſſels.

Laſtly, ſome phyſicians have ſuccefsfully uſed it in diſeaſes of the muſcles, the palſy, lameneſs, &c. by rubbing the ſkin with it, or expoſing it to its fume. Van Helmont conſidered friction with it as a very good remedy againſt colded members, and directed it as an excellent preſervative againſt the impreſſions of cold.

LECTURE XLIII.

Of MINERAL WATERS.

AFTER the hiſtory of all the bodies which compoſe the mineral kindom, and the examination of their phyſical properties, we conclude their account by that of the mineral waters; becauſe, ſince theſe fluids hold diſſolved, frequently, earthy, ſaline, and metallic matters together or ſeparately, it was impoſſible to comprehend their exiſtence, without being previouſly acquainted with the principles which mineralize them. Beſides, we place the inveſtigation of the mineral waters with more advantage here, as it will ſerve as a recapitulation of what has been already delivered upon the minerals, the methods of analyſing them recalling to mind the moſt part of the principles.

§ 1. *Definition and Hiſtory of the Mineral Waters.*

THE name of *mineral waters* has been given to thoſe fluids which contain any minerals in ſolution. However, as there is not a water, even among the pureſt which nature produces, which is not impregnated with ſome of theſe ſubſtances, this name ought to be reſtricted to thoſe which hold a ſufficiency of matter diſſolved, to have a ſenſible effect upon the animal-œconomy, and to have the property of curing or preventing the diſeaſes to which our bodies are liable [*]: on this account the name of *medicinal waters* would appear better ſuited to theſe fluids than that by which they are commonly known, and which uſe forbids us to change.

The firſt acquaintance we had with mineral waters was owing to chance, as is the caſe with all the knowledge which man poſſeſſes. The good effects which they produce upon thoſe who made uſe of them, were undoubtedly the cauſe of their diſtinction from common waters. Ancient philoſophers, who conſidered their properties, paid little attention, except to their ſenſible qualities; ſuch as the colour, the weight or lightneſs, the ſmell, and taſte.

Pliny, however, diſtinguiſhed a great number of waters, either from their phyſical properties, or from the utility reſulting from their uſe. But not until the ſeventeenth century were the methods begun to be found out of inveſtigating the different principles, which they held diſſolved, by making them the ſubject of experiments, which chemiſtry alone was able to conduct. Boyle, in his beautiful Experiments upon Colours, which he publiſhed at Oxford *anno* 1663, among the firſt chemiſts made known ſeveral teſts, capable of indicating by the al-

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[*] It ſhould be obſerved, that waters which contain no ſenſible principles upon analyſis, may, however, produce remarkable effects upon the animal-œconomy; to do this, they only require to be very light, very briſk, and their temperature exceeds that of common waters. Such is the cauſe of the action of the waters of Plombières and Luxeuil, which differ from pure waters only in their warmneſs.

alteration of the colour thoſe ſubſtances which were diſſolved in water.

The Academy of Sciences, at its inſtitution, was ſenſible of the great importance of the analyſis of waters; and Duclos, in the year 1667, undertook the examination of thoſe in France. This chemiſt's inveſtigation of the ſubject is found in the ancient memoirs of this Company. Boyle ſtudied the ſubject towards the end of the ſeventeenth century, and publiſhed a work upon this ſubject, *anno* 1685. Boulduc, 1729, publiſhed a method of analyſing waters, much more perfect than any that had appeared before him: it conſiſts in evaporating their fluids; ſtopping at different times to ſeparate by filtration the ſubſtances which are depoſited as the evaporation advances.

Several celebrated chemiſts after that had great ſucceſs in their inveſtigation of waters. Every one of them made valuable diſcoveries relating to the different principles contained in theſe fluids. Thus Boulduc found natrum in them, of which he has determined the nature. M. le Roi, a phyſician at Montpelier, found ſome calcareous marine ſalt; M. Margraaf ſome marine ſalt with baſe of magneſia; Dr Prieſtley ſome aërial acid; Meſſrs Monnet and Bergman hepatic gas. Theſe two laſt-mentioned chemiſts, beſides the diſcoveries with which they have enriched the analyſis of waters, have given alſo complete treatiſes upon the manner of proceeding in this analyſis, and have carried this part of chemiſtry to a much higher degree of preciſion than had been done before them. Beſides, particular analyſes of ſeveral mineral waters are extant, which have been made by very able chemiſts, and throw great light upon this matter, that has been juſtly conſidered as the moſt difficult of all chemical inveſtigations. The limits which we muſt neceſſarily preſcribe to ourſelves, hinder us from entering into the details to be found in every work: however, we ſhall carefully mention the authors of the diſcoveries as opportunity ſhall offer.

§ 2. *Prin-*

§ 2. *Principles contained in Mineral Waters.*

It is a few years ago only that all the ſubſtances which may be diſſolved in mineral waters were found out. We eaſily ſee the reaſon of this; Chemiſtry had not then acquired all the knowledge requiſite for the determination of the nature of theſe ſubſtances; and it is in proportion to the diſcovery ſolely of certain teſts, that their exiſtence has been aſcertained. Another reaſon, which has alſo retarded the progreſs of the ſcience on this head, is, that the mineral ſubſtances diſſolved in waters are almoſt always only in very ſmall quantity; and beſides, they are always mixed ſeveral together, ſo that they cover reciprocally their diſtinct properties. However it be, the multiplied reſearches of the chemiſts juſt now mentioned, and of a great number of others to be mentioned afterwards, have diſcovered, that there are ſeveral mineral ſubſtances to be very frequently found in waters; that ſome are found but rarely, and others never. Let us take a view of each claſs of theſe ſubſtances, according to the order in which we have examined them.

The quartzy earth is ſometimes ſuſpended in waters; and as it is in a very great ſtate of diviſion, it remains ſuſpended in them without precipitating; but its quantity is always exceedingly ſmall.

Clay alſo ſeems to be found in them: the extreme fineneſs of this earth, which cauſes it to be found diſtributed through all its parts, is at the ſame time the cauſe of their tranſparency being affected. Indeed, the argillaceous waters are whitiſh, and of a pearl or opal colour: they are alſo greaſy to the touch; and are called *ſoapy*.

Lime, magneſia, terra ponderoſa, are never pure in waters; they are always combined with acids.

Nor are the fixed alkalis to be found in their pure ſtate; but they are frequently found in the ſtate of neutral ſalts.

The ſame is the caſe with the volatile alkalis, and with the moſt part of the acids. Nevertheleſs, the aërial acid is often uncombined, poſſeſſing all it properties in waters. It conſtitutes even a particular claſs of mineral waters, known by the appellation of *gaſeous*, *ſpirituous*, or *acidulated waters*.

Among the perfect neutral ſalts, there are few, except Glauber's ſalt, marine ſalt, febrifugal ſalt, and mild fixed mineral alkali, which are often held diſſolved in mineral waters. Nitre and mild vegetable alkali are found very rarely.

Selenite, calcareous marine ſalt, chalk, Epſom ſalt, marine ſalt with baſe of magneſia, and magneſia united with the aërial acid, are the earthy neutral ſalts moſt commonly to be found in waters. As for calcareous nitre and nitrous magneſia, of which ſome chemiſts have told us, theſe ſalts are generally found only in ſaline waters, and almoſt never in mineral waters properly ſo called.

The argillaceous neutral ſalts, and thoſe with baſe of terra ponderoſa, are almoſt never diſſolved in waters: alum ſeems to exiſt in ſome *.

Pure inflammable gas has not yet been found to be diſſolved in mineral waters.

Pure ſulphur has not been found in theſe fluids. Sometimes, though very rarely, it exiſts in ſmall quantity in the ſtate of liver of ſulphur; but for the moſt part it is the hepatic gas, or the vapour of liver of ſulphur, which mineraliſes and conſtitutes the ſulphureous waters.

Laſtly, among the metals, iron is the moſt frequently diſſolved in waters: and it may be found in two ſtates; either combined with the aërial or vitriolic acid.

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* We do not ſpeak of the opinion of Givre and other chemiſts, who conſider alum as one of the moſt conſtant principles of mineral water; but of the accurate analyſis from which M. Mitouart found that alum exiſted in the waters of Dominique de Vals, and M. Opoix the ſame ſalt in thoſe of Provins.

Several chemiſts have thought, that it might be diſſolved in its metallic ſtate, and without the intermedium of an acid. But as this metal almoſt never exiſts in nature, but in that of ruſt or in the ſtate of a vitriol, the opinion of theſe learned men could not be adopted, unleſs when the aërial acid was not known, and when people were at a loſs to conceive the ſolubility of iron in water without the help of the vitriolic acid.

With reſpect to the bitumen, which ſeveral authors have admitted in waters, down to the time of M. le Roy, the moſt part of chemiſts at preſent deny its exiſtence. In fact, as it was particularly from the taſte that this oily ſubſtance was ſuſpected in waters, it is known, that this taſte, which does not belong to the bitumen, depends entirely upon calcareous marine ſalt. It is not difficult to conceive how water, which runs in the heart of the globe, and particularly of mountains, may become impregnated with the different ſubſtances juſt now enumerated. It is alſo conceivable, from the nature of the layers of earth over which the waters run, why they are more or leſs impregnated with principles, why the quantity and nature of theſe principles ſometimes vary; particularly if we conſider the change of direction which theſe fluids may ſuffer from the multiplied alterations of which the globe is ſuſceptible, eſpecially at its ſurface, and in the more elevated grounds.

§ 3. *Different Claſſes of Mineral Waters.*

From what we have juſt now related concerning the different ſubſtances generally contained in mineral waters, it is evident, that we might form as many claſſes of theſe fluids as there are earthy, ſaline, and metallic bodies, which may be held diſſolved; and thus the number of claſſes might be very conſiderable. But it muſt be here obſerved, that none of theſe ſubſtances mentioned is found alone and uncombined in the waters; on the contrary, they are often found diſſolved in the number three, four, five, or more. This, then, is a difficulty which prevents us from making a methodical diviſion of the waters with reſpect to the principles which they contain. However, by attending to that ſubſtance which is moſt copious, and poſſeſſes moſt powerful properties, we ſhall have a diſtinction which, though not extremely exact, will ſuffice to characteriſe and facilitate our judgment of each of theſe fluids. This is the plan of moſt of the chemiſts who have inveſtigated the properties of mineral waters in general. M. Monnet has eſtabliſhed three claſſes of mineral waters; alkaline, ſulphureous, and ferrugineous. The diſcoveries that have been made ſince his time require their diſtribution into a greater number of claſſes. M. Duchanoy, who has publiſhed an eſtimable work upon the art of imitating mineral waters, diſtinguiſhes ten; to wit, the gaſeous, the alkaline, the earthy, the ferrugineous, the ſimple warm waters, the gaſeous warm waters, the ſaponaceous, the ſulphureous, the bituminous, and ſaline. Although this author may be blamed for having multiplied the claſſes of waters, ſince no pure gaſeous and bituminous waters are known, his diviſion is without contradiction the moſt complete, giving a moſt accurate idea of the nature of the different mineral waters, and beſt adapted to its ſubject. For the ſake of an orderly arrangement of the waters relatively to the principles which they contain, and in order to complete what we have already ſaid upon the ſubject, we ſhall propoſe a leſs extenſive diviſion, and one which ſeems more methodical than that of M. Duchanoy; obſerving, that we do not conſider the ſimple hot waters as mineral ones, they being taken by the beſt chemiſts only for hot water; nor ſhall we ſay any more of the bituminous waters, being unacquainted with any ſuch real ones in nature.

Claſs I. *Acidulous Waters.*

THE gaſeous waters, which we would rather call *acidulous*, are thoſe in which the aërial acid prevails. They are diſtinguiſhable by their ſharpneſs and facility in boiling and forming bubbles by ſimple agitation. They redden the tincture of turnſol, precipitate lime-water and liver of ſulphur. As no waters are as yet known which contain only this acid pure and uncombined, we are of opinion, that we ſhould ſubdivide this claſs into ſeveral orders, according to the other principles which are contained in them, or according to the modifications which they exhibit. All appear to contain more or leſs alkali and calcareous earth; but their different degrees of heat furniſh a very good method of dividing them into two orders. The firſt comprehends the acidulous and alkaline cold waters; ſuch as thoſe of Seltz, Sainte Myon, Bard, Langeac, Chateldon, Vals. In the ſecond order we would place the acidulated and alkaline hot waters; as thoſe of Mount d'Or, Vichy, Chatelguyon, &c.

Claſs 2. *Saline Waters.*

We underſtand, as M. Duchanoy does, by the term *ſaline waters*, thoſe which contain a very great quantity of neutral ſalts in ſolution, ſo as to affect in a very remarkable manner, and for the moſt part as purgatives do, the animal-œconomy. The theory and nature of theſe waters are eaſily diſcovered: they are entirely ſimilar to ſolutions of ſalts made in our laboratories; only they contain almoſt always two or three different kinds of ſalts. Glauber's ſalt is very rare; Epſom, marine, and calcareous marine ſalts, are the ſaline principles by which, together or ſeparately, they are mineraliſed. The waters of Sedlitz, Seydſchutz, Egra, are charged with Epſom ſalt, frequently mixed with calcareous marine ſalt. Thoſe of Balaruc contain marine ſalt, chalk, and ſome marine ſalt with earthy baſe; thoſe of Bourbonne, marine ſalt, ſelenite, and chalk; thoſe of Mothe are more compound than the preceding, and hold diſſolved marine ſalt, ſelenite, chalk, Epſom ſalt, marine ſalt with baſe of magneſia, and an extractive matter. It is to be here obſerved, that the ſalts with baſe of magneſia are much more common in waters than has been hitherto thought, and that there are ſtill few analyſes in which they have been properly known, and in a particular manner well diſtinguiſhed from calcareous marine ſalt.

Claſs 3. *Sulphureous Waters.*

THE name of *ſulphureous* has been given to thoſe mineral waters which appear to poſſeſs ſome of the properties of ſulphur; as the ſmell, and the power of colouring ſilver. Chemiſts were long ignorant of the true mineraliſing principle of theſe waters. Moſt of them believed it to be ſulphur; but they never were able to demonſtrate its exiſtence, or at leaſt they never found any atoms of it. Thoſe who ſet about the ſtudy of ſome of theſe waters, admitted in them either a ſulphureous ſpirit or liver. Meſſrs Venel and Monnet firſt oppoſed this opinion. The latter has very nearly come to the truth; he conſiders the ſulphureous waters to be impregnated ſolely with the vapour of liver of ſulphur. M. Rouelle the younger has told us, that theſe fluids may be alſo imitated, by agitating water with air diſengaged from liver of ſulphur by means of an acid. M. Bergman has greatly enlarged this doctrine, having examined the properties of hepatic gas, of which we have taken notice in the article *Sulphur:* he has proved, that it is this gas which mineraliſes the ſulphureous waters, which he has on this account called *hepatic;* and he gives teſts for diſcovering the preſence of ſulphur. Notwithſtanding theſe diſcoveries, M. Duchanoy, in ſpeaking of the ſulphureous waters, admits in them liver of ſulphur, ſometimes alkaline, calcareous, or argillaceous; and in this opinion he follows M. le Roy of Montpelier, who, as we have ſaid in the hiſtory of Sulphur, propoſed to imitate theſe waters, by making a liver of ſulphur with baſe of magneſia. Perhaps there are waters which contain really a little liver of ſulphur, whilſt others are mineraliſed only by hepatic gas. In this caſe, it would be neceſſary to diſtinguiſh two orders of ſulphureous waters. Thoſe might be perhaps called *hepatic* which contain a little native liver of ſulphur; and *hepatiſed*, thoſe which are impregnated with hepatic gas. The waters of Bareges, Cauterets, and Bonn, ſeem to belong to the firſt order; and thoſe of Saint Amant, Aix-la-Chapelle, and Montmorency, to the ſecond. All theſe are hot waters.

Claſs 4. *Ferrugineous Waters.*

IRON being the moſt copious and moſt alterable metal, it is no wonder that water is eaſily impregnated with it. On this account, ferrugineous waters are the moſt abundant and common of the mineral waters. Modern chemiſts have thrown much light upon this claſs of waters. Anciently they were all believed to be vitriolic. M. Monnet has aſſerted, that the moſt of them contain no vitriol; and he has thought that the iron was diſſolved without the intervention of an acid. At preſent, it is known that iron, which is not in the ſtate of vitriol, is diſſolved by means of the aërial acid, and forms the ſalt which we have called *creta ferrea.* Meſſrs Lane, Rouelle, and ſeveral chemiſts, have put this truth out of doubt. The greater or leſs quantity of aërial acid, and the ſtate of the iron in the waters which owe to it their virtues, lead us to diſtinguiſh this fourth claſs into three orders. The firſt comprehends the martial acidulous waters in which the iron is held diſſolved by the aërial acid; the ſuperabundance of which renders them ſharp and ſouriſh. The waters of Buſſang, Spa, Pyrmont, Pougue, and Dominique of Vals, are of this firſt order. The ſecond comprehends the ſimple martial waters, in which the iron is diſſolved by the aërial acid not to exceſs; and conſequently theſe waters are not acidulous. Thoſe of Forge, Aumale, Condé, as alſo the greateſt number of ferrugineous waters, are of this order. This diſtinction was made by M. Duchanoy: but we add a third order from

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M. Monnet; the vitriolic waters. Although theſe waters be extremely rare, ſuch however exiſt. Into this order M. Monnet put the waters of Paſſy. M. Opoix admits the vitriol of mars, and even in very great quantity, to be in thoſe of Provins: it is true that M. de Fourcy has denied its exiſtence, and conſiders the iron of theſe waters to be diſſolved by fixed air: but we cannot be deciſive on this point; for the reſults of theſe chemiſts are entirely oppoſite, and require a new examination. It muſt be added, that iron is not found alone in waters; it is mixed with chalk, ſelenite, and marine ſalts, with magneſia, lime, or the alkalis as baſes. However, as the metal which they contain is the principle baſe of their properties, they ought to be called *martial*, from the principles which we have eſtabliſhed *.

As to the ſaponaceous waters admitted by M. Duchanoy, we muſt wait, in order to give our opinion upon this head, till chemical and medical knowledge determine the cauſe of their ſaponaceous property which this phyſician attributes to clay, and of the effects which they, as medicines, may produce upon the animal-œconomy on account of this property.

§ 4. *Examination of Mineral Waters from their Phyſical Properties.*

AFTER having given a view of the different ſubſtances which may be collected in the waters, and after a ſlight ſketch of the manner in which they may be divided into claſſes and orders, from the principles they contain; it becomes neceſſary to mention the methods of analyſis, and of aſcertaining, with the utmoſt preciſion,

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* In the enumeration of the waters divided into claſſes, we do not ſpeak of thoſe which contain arſenic and copper, becauſe they are conſidered as poiſons. We likewiſe paſs over the waters which contain volatile alkali or ſal ammoniac, which is the production of the putrefaction of organic matters upon which they have been ſtagnant: Theſe kinds of waters do not belong to the medicinal waters.

ſion, the ſubſtances which they hold in ſolution. This analyſis has been looked upon as the moſt difficult part of chemiſtry; and with the greater reaſon, on this account, that a complete knowledge of all the chemical phenomena, joined to the habit of making experiments, is required: and upon that account we have placed this article at the end of the mineral kingdom. In order to obtain a precife knowledge of any water which we wiſh to examine, 1ſt, The ſituation of the ſource muſt be obſerved, the neighbourhood deſcribed with exactneſs, and particularly the layers of minerals of which the ſoil is compoſed: parcels of the ſoil at different depths muſt be taken; and from inſpection, we endeavour to find the ſubſtances which may impregnate the water. 2dly, Then we examine the phyſical properties of the water; ſuch as its taſte, ſmell, colour, tranſparency, weight, temperature. For this purpoſe, we ought to be ſupplied with two thermometers which nearly tally with each other, and which are made of a weighty liquor: and theſe preliminary experiments ought to be made in different ſeaſons, at different hours of the day, and at different times, according to the ſtate of the atmoſphere. A long-continued drought, or copious rains, have ſingular influence upon the waters. Theſe previous eſſays generally point out the claſs to which the water ought to be referred, and direct the reſt of the analyſis. 3dly, The depoſitions at the bottom of the channels, the ſubſtances which ſwim upon the water, and the ſublimed matters, are alſo of ſuch importance as not to be overlooked. Then we proceed to the analyſis; which is made in three ways, by means of teſts, diſtillation, and evaporation.

§ 5. *Examination of the Mineral Waters by Teſts.*

THE name *teſts* has been given to the ſubſtances which are mixed with the waters, in order to know, from the phenomena which preſent themſelves, the nature of the ſubſtances which the waters have diſſolved.

The beſt chemiſts have always conſidered the uſe of teſts as a very uncertain means to diſcover the principles of mineral waters; upon this account, that their action did not indicate, in an exact manner, the nature of the ſubſtances diſſolved; becauſe we were often ignorant of the cauſe of the changes produced in theſe fluids by their admixture: and in fact, the ſaline ſubſtances which are generally employed in analyſis, are capable of producing a great number of phenomena, of which it is very difficult to give our opinion. On this conſideration, the moſt part of thoſe who have ſtudied this ſubject, have had little confidence to put in teſts; they have believed, that evaporation was a much more certain method of aſcertaining the nature and quantity of the principles of mineral waters: and in the beſt accounts of the analyſis of theſe fluids, it is conſtantly recommended to make uſe only of theſe ſubſtances as auxiliaries, which are at moſt capable of ſhowing or cauſing the ſuſpicion of the nature of the principles which conſtitute thoſe waters. On this account, modern analyſers have admitted only a certain number of teſts, and have greatly diminiſhed the liſt of thoſe which the firſt chemiſts had employed.

However, we cannot at preſent doubt, but that the heat which is neceſſary to evaporate the waters, however feeble it may be, may produce ſenſible alterations in their principles; and ſo ſtrip them of their nature, that their reſiduum, examined by the different means which chemiſtry furniſhes, yields compounds quite different from thoſe which were held in ſolution in the waters. The loſs of the gaſeous ſubſtances which often make one of the active principles of mineral waters, changes their nature in a ſingular manner; and, beſides the precipitation of ſeveral bodies which owe their ſolubility only to the preſence of theſe volatile bodies, produces a reaction between the fixed matters which alter their properties. The phenomena of the double decompoſitions which heat is capable of producing, be-

between compounds which have no mutual action in the cold, are not be comprehended without a numerous ſet of experiments, about which we can have as yet only conjectures. Without entering into long details, it will be ſufficient for us to know, that this aſſertion is clearly demonſtrated to all chemiſts, ſo as to convince us, that we muſt not depend entirely upon evaporation. Does no method, then, remain of aſcertaining the particular nature of the ſubſtances diſſolved in mineral waters, without having recourſe to heat? and does the complete knowledge of modern compoſitions, which have extended chemiſtry ſo far, contain no proceſs, with a view to correct the errors into which evaporation may lead us? The account which I am going to give, and which I extract from a memoir that I read to the Royal Society of Medicine, will prove, that the teſts which are in a very pure ſtate, and which are employed in a particular manner, may be much more uſeful in analyſing the mineral waters than has hitherto been imagined.

Among the conſiderable number of teſts which have been propoſed for the analyſes of mineral waters, thoſe from which we ſhould expect the greateſt light are, the tincture of turnſol, ſyrup of violets, lime-water, cauſtic fixed alkali, volatile cauſtic alkali, oil of vitriol, nitrous acid, the ley, ſaturated with the colouring part of Pruſſian blue, the ſpiritous tincture of the gall-nut, and the nitrous ſolutions of mercury and ſilver. To theſe M. Bergman has added paper, coloured by the aqueous tincture of Braſil wood, which becomes blue by the alkalis; the aqueous tincture of terra merita, which theſe ſame ſalts turn to a brown red; the acid of ſugar, to indicate the preſence of the ſmalleſt poſſible quantity of lime; and ſeveral others, which have been propoſed by moſt of the chemiſts: but thoſe which we have mentioned, ſuffice to aſcertain all the ſubſtances contained in mineral waters.

The effects and uſe of theſe principal teſts have been plained by all the chemiſts; but enough has not been ſaid about their ſtate. Before they are uſed, it is of great importance to know exactly their nature, that we may not be deceived in their effects. M. Bergman has explained at great length the alterations which they are capable of producing. This celebrated chemiſt ſays, that a paper coloured with the tincture of turnſol, aſſumes a deeper blue by the alkalis, but is not altered by fixed air or the aërial acid. As it is chiefly to diſcover the preſence of this acid that this colouring-part is uſeful, he directs uſing only its tincture in water with proper dilution, that it may take a blue colour. He rejects entirely the ſyrup of violets, becauſe it is ſubject to fermentation, and becauſe it is never got genuine in Sweden. M. de Morveau, in a note, adds, that it is eaſy to diſtinguiſh a ſyrup, coloured by bluebottle or tournſol, by means of corroſive ſublimate, which gives it a red colour; whereas it renders the ſyrup of violets green.

Lime-water is one of the moſt uſeful teſts in the analyſes of mineral waters, though few chemiſts have made expreſs mention of it in their works. This fluid decompoſes the metallic ſalts, particularly martial vitriol, from which it precipitates the iron. It ſeparates clay or magneſia from the vitriolic and marine acids, to which theſe ſubſtances are frequently joined in mineral waters. It can alſo ſhow, by precipitation, the preſence of aërial acid. M. Gioanetti, phyſician at Turin, has made a very ingenious uſe of it, to diſcover the quantity of aërial acid in the waters of St Vincent. This chemiſt, after having obſerved that the bulk of this acid, from which its quantity is always judged, might vary according to the temperature of the atmoſphere, mixed nine parts of lime-water with two parts of water of St Vincent. He found the exact weight of the calcareous earth, formed by the junction of the aërial acid of the mineral water with the lime of the lime-water; and he found, according to the calculation of M. Jacquin, which demonſtrates the exiſtence of thirteen ounces of this acid in thirty-two ounces of chalk, that the water of St Vincent contained a little more than fifteen grains: but as the lime-water might ſeize upon the aërial acid joined to the fixed alkali, as well as that which is free, M. Gioanetti, to diſcover the quantity of this laſt, made the ſame experiment with water deprived of its free acid by means of boiling. This proceſs might then be employed, to determine exactly, and in an eaſy manner, the weight of free aërial acid in any gaſeous mineral water.

One of the principal reaſons which have led chemiſts to conſider the action of teſts in the analyſis of mineral waters as very uncertain, is, that they may ſhow ſeveral ſubſtances diſſolved in the mineral waters; and it is on this account very difficult to know exactly the effect which they produce. This truth reſpects particularly the fixed alkali conſidered as a teſt, ſince it decompoſes all the ſalts formed by the union of the acids with clay, magneſia, lime, and the metallic ſubſtances. When the alkali precipitates a mineral water, we cannot know by inſpection alone the nature of the earthy ſalt decompoſed in this experiment. Its effect is ſtill more uncertain when it is employed at the point of ſaturation with aërial acid, as it is generally done, ſince the acid which is united with it may increaſe the confuſion. On this account I propoſe the uſe of the cauſtic alkali in its very pure ſtate. It has alſo an advantage that the mild alkali does not poſſeſs; which is that of ſhowing the preſence of chalk, diſſolved in a gaſeous water by means of the ſuperabundant aërial acid. As it ſeizes upon the ſuperabundant part, the chalk, which ceaſes to be longer ſoluble in the water, precipitates. I have aſſured myſelf of this fact, by pouring ſome of the ſoap-boilers ley, freſh made, into an artificial gaſeous water, which kept chalk in ſolution.: the chalk precipitated in proportion as the cauſtic fixed alkali ſeized upon the aërial acid which kept it diſſolved. By filtration, and evaporation to dryneſs, I obtained ſome ſal ſodæ, making a very briſk efferveſcence with ſpirit of vitriol. The cauſtic fixed alkali may alſo occaſion a precipitates in the mineral waters, without their containing earthy ſalts: it is enough that they hold diſſolved a leſs ſoluble alkaline neutral ſalt, and then the alkali precipitates it by uniting with the water, juſt as ſpirit of wine does. M. Gioanetti obſerved this phenomenon in the waters of St Vincent; and it is alſo eaſy to convince one's ſelf of this, by pouring ſome cauſtic alkali into a ſolution of vitriolated tartar or marine ſalt, and theſe two ſalts are ſoon precipitated.

The cauſtic volatile alkali is in general leſs ſuſceptible of error when it is mixed with mineral waters; becauſe it decompoſes only the ſalts with earthy baſes, as clay and magneſia, without affecting calcareous ſalts. But it is of importance to make two obſervations on this head: the firſt is, that we muſt have the alkali in its moſt cauſtic ſtate, containing not an atom of aërial acid: without this precaution, it decompoſes the ſalts with baſe of lime by means of double affinity; the ſecond is, that we muſt not leave this mixture expoſed to the air, when we wiſh to know its action ſeveral hours after it has been made; becauſe, as M. Gioanetti has very well obſerved, this ſalt ſeizes in a little time upon the aërial acid of the atmoſphere, and becomes capable of decompoſing the calcareous ſalts.

To leave no doubt upon this important ſubject, I made three deciſive experiments. After having diſſolved in diſtilled water ſome grains of ſelenite, made with tranſparent calcareous ſpar and ſpirit of vitriol, an indiſpenſable precaution, becauſe the chalk or Spaniſh white contains magneſia as well as river-water does, I divided the ſolution into two parts. Into the firſt I poured a few drops of recently prepared and very cauſtic volatile alkali: I put this mixture into a well-ſhut phial: in twenty-four, even forty-eight hours after, it was clear and tranſparent, without any depoſition: no decompoſition, then, had taken place. The ſecond portion

tion was heated in the ſame way; but was put into a veſſel whoſe large opening communicated with the air: in a few hours, on the ſurface, a cloud was formed, which augmented in thickneſs, and at laſt precipitated. This depoſition made a briſk effervefcence with ſpirit of vitriol, and formed ſelenite. The aërial acid which this precipitate contained had therefore been ſupplied by the volatile alkali, which had attracted it from the atmoſphere. This combination of the aërial acid and alkaline gas forms aërated ſal ammoniac, capable of decompoſing the calcareous ſalts by means of a double affinity, as has been demonſtrated by Meſſrs Black, Jacquin, and ſeveral other chemiſts; of which we may make ourſelves certain, by pouring a ſolution of concrete volatile alkali into a ſolution of ſelenite, which the volatile cauſtic alkali does not affect. Laſtly, to be confirmed in the etiology of this ſecond experiment, I took the firſt portion, which was united with the cauſtic volatile alkali, and was preſerved in a cloſe veſſel, and had loſt nothing of its tranſparency. I put the veſſel which contained it upon the ſyphon of a very ſmall pneumato-chemical apparatus, and directed into this mixture the aërial acid which was iſſuing from an effervefcing mixture of fixed alkali and ſpirit of vitriol. As the bubbles of this acid paſſed through the mixture, it turned turbid, as lime-water does. After filtration, chalk was found upon the filtre; and the water, when evaporated, yielded vitriolic ammoniac. The aërial acid ſpirit produced the ſame decompoſition in another mixture of pure ſelenite and cauſtic volatile alkali. This deciſive experiment completely proves, that it is ſolely by means of the double affinity, which inſtantly takes place by the addition of the aërial acid, that the volatile alkali becomes capable of decompoſing ſelenite. Hence it is evident, that when we are to keep the mixture of a mineral water with the volatile alkali during ſeveral hours, as is neceſſary, becauſe it decompoſes certain earthy ſalts but very ſlowly, this experi-

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ment ought to be made in a veſſel which can be completely ſhut up, to prevent the contact of the air from producing a falſe reſult. This precaution is in general of very great importance in the uſe of all the teſts. It is beſides recommended by Meſſrs Bergman and Gioanetti.

I ſhall add one obſervation upon the uſe of the volatile alkali. As it is very difficult to have volatile alkali perfectly cauſtic, in which ſtate it muſt be when employed to analiſe mineral waters, a very ſimple means may be employed, which I have practiſed with ſucceſs. It conſiſts in pouring a little volatile alkaline ſpirit into a retort whoſe neck is immerſed into the mineral water; by the application of a gentle heat to the retort, the alkaline gas is diſengaged, and paſſes over very cauſtic into the water. If a precipitate appears, the mineral water contains ſome martial vitriol, which is proved conſtantly by the colour of the precipitate, or ſalts with baſe of earth, of alum, or of magneſia. It is very difficult to judge by the phyſical properties of the earthy precipitate, formed in a water by the cauſtic volatile alkali, to which of theſe two laſt baſes the precipitate ought to be referred. However, the manner in which it is formed may tell what its character is. By diſſolving ſix grains of Epſom ſalt in four ounces of diſtilled water, and ſix grains of alum in an equal quantity; and by directing into each of theſe ſolutions a little alkaline gas, that of the Epſom ſalt was inſtantly turned turbid, whilſt that of the alum began to precipitate only in twenty minutes after. Care had been taken to put the mixture into a veſſel cloſely ſhut. The ſame phenomenon happens with the nitrous and marine ſalts with baſe of magneſia and earth of alum, when diſſolved in equal quantity in diſtilled water, and managed with the ſame precautions. The celerity or ſlowneſs of precipitation of a mineral water by the addition of the alkaline gas, thus ſerves to ſhow what is the earthy ſalt decompoſed. In general, the ſalts with baſe of magneſia are infinitely more common in the mineral waters than thoſe with baſe of aluminous earth. I ſhould not forget mentioning a fact obſerved by M. Bergman; which is, the volatile alkali is ſuſceptible of forming with Epſom ſalt a compound, in which an undecompoſed portion of this neutral ſalt is combined with a portion of Glauber's ſecret ammoniacal ſalt. Perhaps this undecompoſed portion of Epſom ſalt forms with the vitriolic ammoniac a mixed neutral ſalt, analagous to ſal alembroth. The volatile alkali then precipitates only a part of the magneſia, and cannot exactly determine the quantity of Epſom ſalt, of which it is the baſe. For this reaſon, lime-water appears to me preferable for aſcertaining the nature and quantity of the ſalts with baſe of magneſia contained in mineral waters. It has alſo the property of precipitating the ſalts with baſe of aluminous earth, much more copiouſly and readily than alkaline gas does *.

The concentrated vitriolic acid precipitates of a dirty white a water containing terra ponderoſa, according to M. Bergman: but as this earth, according to him, is very rarely found in mineral waters, I muſt proceed to the other effects of this teſt. When it produces bubbles in a water, it ſhows the preſence of chalk, mild fixed alkali, or pure aërial acid. Each of theſe ſubſtances may be diſtinguiſhed by particular phenomena. If a water charged with chalk is heated, into which ſome vitriolic acid has been poured, a pellicle and a ſelenitical depoſition is readily formed; which does not happen in ſimple alkaline waters. At firſt view, it would appear, that the ſelenite ought to precipitate as ſoon as the vitriolic acid is poured into a water containing chalk.

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* It will be eaſily perceived that I repeat ſeveral facts which have been already explained through the work. I do this deſignedly, in order to render this ſmall account of the analyſis of waters more clear and complete; and to collect, about the means of their analyſis, all the knowledge which I imagine indiſpenſably neceſſary for the ſtudy of this ſubject.

chalk. However, this very rarely happens without the aid of heat; becauſe theſe waters contain for the moſt part a ſuperabundance of aërial acid which promotes the ſolution of the ſelenite; and it is requiſite to deprive them of this acid before this ſalt can be ſeparated. We may be convinced of this by throwing a few drops of concentrated vitriolic acid into a certain quantity of precipitated lime-water, and afterwards made clear by aërial acid. If the lime-water abounds greatly with regenerated calcareous earth, a ſelenitical precipitate falls in a few minutes, or more ſlowly and in proportion to the diſſipation of the free aërial acid. If it does not fall by ſimple repoſe, as it happens when the water contains but little ſelenite and a great quantity of ſuperabundant aërial acid, a ſlight heat is enough to form a ſelenitical pellicle and precipitate.

Concentrated ſpirit of nitre is recommended by M. Bergman to precipitate ſulphur from hepatic waters, formerly called *ſulphureous*. Without adopting the theory of this celebrated chemiſt, which conſiders the hepatic gas as ſulphur converted into a gaſeous ſtate by heat and phlogiſton; without thinking, with him, that heat precipitates the ſulphur from them by ſeizing upon the phlogiſton and diſengaging the heat, I have thought proper to mention this method, which is very uſeful to diſcover the preſence of ſulphur in ſulphureous or hepatic waters. To be aſſured of this fact, it is ſufficient to pour a few drops of fuming ſpirit of nitre into diſtilled water, which has been, by means of a pneumato-chemical apparatus, impregnated with the gas diſengaged from cauſtic liver of ſulphur heated in a retort. This artificial hepatic water, which ſlightly differs from the natural ſulphureous waters in this, that it is difficult of filtration, and appears always a little whitiſh, gives in a few moments a precipitate with nitrous acid. This precipitate is of a yellowiſh white; collected upon a filtre and dried, it burns with the flame and ſmell peculiar to ſulphur, of which it poſſeſſes all the characters.

ers. It ſeems that ſpirit of nitre alters hepatic gas, as t does all inflammable matters by means of the great quantity of pure air which it contains. If it is the only acid poſſeſſing this property, it is owing to the very inconſiderable union of the air, which makes a conſtituent principle in this acid. For the ſame reaſon, it acts upon all combuſtible matters, and reduces them to the ſtate of burnt bodies much more rapidly than the other acids.

No agent is as yet ſo little known, with regard to the manner of its acting, as the phlogiſticated alkali. It is a long time ſince chemiſts knew that this liquor, prepared with ox-blood, contained Pruſſian blue already formed. It has been imagined, that this blue might be ſeparated by means of an acid; and in this ſtate it has been propoſed as a ſubſtance capable of demonſtrating the exiſtence of iron in mineral waters. The late M. Bucquet having obſerved, that a phlogiſticated alkali, precipitated by an acid, ſtill contained Pruſſian blue, which was gradually precipitating, took care to ſeparate this blue by filtration: the alkali depoſited it afreſh; and it was filtered more than twenty times in the ſpace of two years, without being totally deprived of Pruſſian blue. I have ſome of this liquor, prepared more than five years ago; and it ſtill has a pretty blue colour. Might the colouring part of Pruſſian blue be contained in the phlogiſticated ley, as M. Bucquet thought, and as M. Baunach ſaid long ago? However it be, we ought to give up this ley in the employment of teſts. M. Macquer, from his famous diſcovery of the decompoſition of Pruſſian blue by the alkalis, propoſed the liquor, ſaturated with the colouring part of this blue, to detect iron in mineral waters: however, as this liquor contains a little Pruſſian blue, which may be ſeparated from it by an acid, as M. Macquer has ſhown, M. Baumé directs adding to this Pruſſian alkali, two or three ounces of diſtilled vinegar in the pound, digeſting it with a gentle heat till all the blue be precipitated;

tated; then pure fixed alkali is poured upon it, to ſaturate the vinegar. Notwithſtanding this very ingenious proceſs, we have had occaſion to obſerve, I mean M. Bucquet and myſelf, that this Pruſſian alkali, when purified by vinegar, depoſited Pruſſian blue a long time, and particularly by evaporation with heat. M. Gioanetti, whom I have had occaſion to mention ſeveral times with approbation, has made the ſame obſervation, by evaporating to dryneſs the Pruſſian alkali, purified by M. Baumé's proceſs. He has propoſed two methods for obtaining this liquor more pure, and totally exempt from iron. In the one, he directs ſurcharging the Pruſſian alkali with diſtilled vinegar, evaporating it to dryneſs with a gentle heat, diſſolving the remaining maſs in diſtilled water, and filtrating the ſolution. All the Pruſſian blue remains upon the filtre, and the liquor contains no more. The other proceſs conſiſts in neutraliſing this alkali with a ſolution of alum; the vitriolated tartar is filtrated, and ſeparated by evaporation. Theſe two liquors give not an atom of Pruſſian blue with pure acids, nor by evaporation to dryneſs. The volatile alkali, ſaturated with the colouring matter of the Pruſſian blue, has alſo been propoſed, which has the ſame inconvenience, and may be purified in the ſame way. Lime-water ſaturated with the colouring matter of the Pruſſian blue, of which I have ſpoken in the article Iron, does not appear exempt from theſe inconveniences. Poured upon a ſolution of martial vitriol, it forms inſtantly a Pruſſian blue, quite pure, and deſtitute of a green colour. The acids precipitate not an atom of blue from it. It contains, therefore, no iron; and it is preferable to the Pruſſian alkalis for eſſaying mineral waters. This phenomenon undoubtedly depends upon this, that lime, diſſolved in water, has not near the ſame action upon iron as the alkalis have. This Pruſſian lime-water appeared to me well adapted to detect iron in waters, whether gaſeous or vitriolic. For indeed this aërial gas, which holds the iron diſſolved in waters, being of an acid nature, decompoſes as well the Pruſſian leys, by means of the double affinities, as it does the martial vitriol. I tried the Pruſſian lime-water upon the waters of Spa and Paſſy: I inſtantly obtained a blue precipitate, not very remarkable, though ſenſible, in the former, and very apparent in the latter. This, then, is a liquor eaſily prepared, which contains not an atom of Pruſſian blue, and which is very proper to ſhow the preſence of the ſmalleſt quantity of iron in waters. It is a kind of neutral ſalt, formed by the colouring part of the Pruſſian blue and lime.

The gall-nut, as well as all bitter and aſtringent vegetable ſubſtances, as oak-bark, the fruit of the cypreſs tree, the bark of walnuts, have the property of precipitating ſolutions of iron, and giving to this metal different colours, according to its quantity and its ſtate, and according to the ſtate of the water which kept it in ſolution. This colour exhibits a great number of varieties, from a pale roſe to the deepeſt black. It has been diſcovered, that the purple colour which the waters aſſume with the tincture of the gall-nut, is not an indication that iron is contained in a metallic ſtate, as M. Monnet had believed; ſince martial vitriol and iron, united with aëriel acid, which I call *creta martialis*, are likewiſe coloured purple by the infuſion of the gall-nut. It is rather the quantity of the iron, its greater or leſs degree of adherence to the water, and the more forward or backward ſtate of this ſolution's decompoſition, which occaſion the differences of colour, which are obſerved in theſe precipitations, as M. Duchanoy has very well obſerved in his Eſſay upon the Art of imitating Mineral Waaters. Yet, notwithſtanding this teſt has been known and employed with much ſucceſs in the analyſis of mineral waters, ſince the time M. Duclos recommended it in the year 1667, and although Meſſrs Macquer, Monnet, and the Dijon Academicians, have made ſome pretty experiments upon the gall-nut, the nature of the aſtringent principle is ſtill unknown. We can only ſuſpect that it is a kind of particular acid, as it unites with the alkalis, reddens the blue colour of vegetables, decompoſes liver of ſulphur, and combines with the metals. The gall-nut is employed to diſcover the preſence of iron in a mineral water, either in the form of a powder, or its infuſion made in the cold and the tincture with ſpirit of wine. This laſt form is to be preferred, becauſe it is much leſs ſubject to alteration than the ſolution in water, which is very apt to grow mouldy. What is moſt ſingular is, that the products by diſtillation of the gall-nut likewiſe colour martial ſolutions. The ſolution in the acids, alkalis, oils, æther, all preſent the ſame phenomenon. The iron which this matter precipitates from the acids, is in a condition little underſtood, and forms a kind of neutral ſalt, which is not attractible by the magnet, although very black: it diſſolves ſlowly and without a ſenſible effervеſcence in the acids; it loſes theſe properties by the action of the fire, and becomes attractible. The gall-nut is a teſt of ſo vaſt a ſenſibility, that a ſingle drop of its tincture gives, in the ſpace of five minutes, a purple colour to a water containing only a twenty-fourth of a grain of martial vitriol in near three pints of water.

The two laſt teſts I ſhall propoſe in the examination of waters are, the ſolutions of ſilver and mercury in nitrous acid. They have been uſually employed to detect the vitriolic or marine acids; but ſeveral other ſubſtances may likewiſe precipitate themſelves without the need of the preſence of the ſmalleſt quantity of theſe acids. The white and heavy ſtriæ, which a lunar ſolution occaſions in a water containing only half a grain of a marine ſalt in the pint, very eaſily and very ſurely announce the acid of this ſalt. But they do not diſcover in the ſame degree the preſence of the vitriolic acid, as it requires, according to M. Bergman's calculation, at leaſt thirty grains of Glauber's ſalt in a pint of water, to produce an immediate ſenſible effect; add to this, that the fixed alkali, chalk, and magneſia, may, in a much more remarkable

able manner, precipitate the nitrous ſolution: therefore the precipitation of a mineral water by means of this ſolution, cannot be depended upon as an accurate teſt of the preciſe ſaline or earthy ſubſtance to which it is owing.

The nitrous mercurial ſolution is ſtill more apt to miſlead. It not only indicates the preſence of the vitriolic and marine acids in a water, but it is precipitated by the mild fixed alkali, of a yellowiſh powder, which we might miſtake for the effect of the vitriolic acid. A very ſimilar depoſition is cauſed by lime and magneſia. It is commonly believed, that the very copious white precipitate which it forms in a water, is owing to the preſence of a marine ſalt; but the mucilages and extractive ſubſtances exhibit the ſame phenomenon, as all chemiſts now know. Beſides theſe ſources of error and uncertainty, from the property which ſeveral ſubſtances have of producing a ſimilar effect with the nitrous ſolution, we muſt have regard to other properties which depend upon the ſtate of the ſolution itſelf, and of which it is very requiſite we ſhould be warned, ſo as not to commit groſs miſtakes in the analyſis of waters. M. Bergman has taken notice of a few of the ſingular differences which are obſerved in this ſolution, according to the manner in which it has been made in the cold or with heat, chiefly relating to the colour of the precipitates which it gives by different intermedia: but he has not ſaid a word of the property which this ſolution has of being precipitated by lime-water when it is very copious in calx of mercury, although M. Monnet has taken notice of the fact in his Treatiſe upon the Solution of the Metals. As this is of great importance in the analyſis of waters, I ſet about aſcertaining the fact completely; and I ſucceeded in a very ſimple way. I made a great number of ſolutions of mercury in very pure nitrous acid of different quantities of theſe two ſubſtances, without and with heat, and with acids of different degrees

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of ſtrength. Theſe experiments yielded different reſults.

1. The ſolutions made in the cold are more or leſs readily charged with a greater or leſs quantity of mercury according to the concentrated ſtate of the acid; but whatever quantity of mercury is taken up in the cold by a concentrated acid, this ſolution never is precipitated by water. I diſſolved in the cold two gros and a half of mercury in two gros of fuming ſpirit of nitre, weighing an ounce four gros and five grains, in a bottle which contained an ounce of diſtilled water: the combination took place with ſingular rapidity; more than the fourth of the acid was loſt in a very copious thick nitrous gas and aqueous vapours, which were diſcharged by the heat of the mixture: the ſolution was of a deep green, very tranſparent. I poured a few drops of it into an ounce of diſtilled water; ſome whitiſh ſtriæ formed, which were diſſolved by agitation, and gave no precipitate. This is, however, the moſt copious ſolution which I was able to make in the cold, which excites the greateſt motion and effervescence, and moſt deep red vapours. As it had depoſited cryſtals, I added two gros of diſtilled water, which diſſolved the whole without appearance of precipitation. Farther, thoſe made in the cold with ordinary nitrous acid, and half their weight of mercury, never will be precipitated by water, and might be employed ſucceſsfully in the analyſis of mineral waters.

2. However ſmall be the degree of concentration of the nitrous acid, if it is ſtrongly heated upon mercury, it will diſſolve a greater quantity than the ſtrongeſt acid will do in the cold; and the ſolution, ſlightly coloured yellow, will appear thick; it will let fall by repoſe an irregular yellow maſs, which may be changed into a beautiful turbith by means of boiling water. This ſolution, poured into diſtilled water, forms a very copious precipitate of a yellow colour reſembling turbith. A ſolution made in the cold will exhibit the ſame

phenomenon, if it is ſtrongly heated, and if much nitrous gas is diſengaged. Theſe ſolutions with heat ſhould never be uſed in the analyſis of mineral waters, ſince they are decompoſed by diſtilled water.

3. It appears that theſe two kinds of ſolutions differ from one another only in the quantity of calx of mercury, which is much greater in that precipitated by water than that which is undecompoſable by this fluid. I demonſtrated the truth of this preſumption, by evaporating equal quantities of the one and of the other of theſe ſolutions. I obtained a fourth more of this precipitate from the ſolution precipitable by water, than from that which was not precipitable. The ſpecific weight ſeemed ſtill a better means of ſhowing the reſpective quantity of mercurial calx contained in theſe different liquors. I compared the relative weight of an equal volume of three mercurial nitrous ſolutions, which differed from one another. The one not at all precipitable by diſtilled water; and the reſult of the firſt experiment, mentioned above, weighed one ounce one gros and ſixty-ſeven grains in a bottle, which contained juſt an ounce of diſtilled water. The ſecond ſolution had been made by a very gentle heat, and gave a ſlight opal colour to diſtilled water, without producing a very remarkable precipitate; in the ſame bottle it weighed one ounce ſix gros and twenty-four grains. A third mercurial ſolution, ſtrongly heated, which precipitated a true turbith mineral, of a dirty yellow, by means of diſtilled water, weighed in the ſame bulk, one ounce, ſeven gros, and twenty-five grains. To confirm this opinion the more, a deciſive experiment remained to be made. If the ſolution which water precipitated, owed this property to too great a quanty of mercurial calx relatively to the quantity of acid, it ought to loſe this property by the addition of acid neceſſary to ſupport the mercury: it ſo turned out. By pouring ſome aquafortis upon a ſolution which water decompoſed, it became undecompoſable by water; and it was abſolutely in the

ſame ſtate as that which was made ſlowly and by the heat of the atmoſphere alone. M. Monnet has already taken notice of this proceſs, as hindering the cryſtals of mercurial nitre from being reduced into a turbith by the contact of air. By an inverſe proceſs, evaporating a portion of the acid of a proper ſolution which is not precipitated by water, this ſolution is converted into one, which abounds in the calx, and conſequently is precipitable by water. It may regain its firſt quality by reſtoring to it the acid which it loſt during evaporation.

Such are the different conſiderations upon which I have thought proper to enter, to render leſs uncertain the effect of the teſts upon the waters. But however preciſe we may be in theſe inveſtigations; however extenſive our knowledge of the degree of purity, and of the different ſtates of the different ſubſtances which we mix with mineral waters in order to diſcover their principles; if it is only to be alleged, that each teſt is ſuſceptible of indicating two or three different matters diſſolved in theſe waters, a doubt will always remain of the reſult of their action. Lime, for example, attracts aërial acid; it precipitates the ſalts with baſe of clay and magneſia, and alſo the metallic ſalts: the volatile alkali has the ſame effect; the fixed alkali precipitates, beſides theſe ſalts, thoſe with baſe of lime; lime-water, charged with the colouring part of Pruſſian blue, the Pruſſian alkali, and the ſpirituous tincture of the gall-nut, precipitate vitriolum ferri and creta martialis; the nitrous ſolutions of ſilver and of mercury, decompoſe all the vitriolic and marine ſalts, which may vary or be found ſeveral in the ſame water; they themſelves are decompoſed by the alkalis, chalk, and magneſia. Amongſt this great number of complicated effects, how are we to diſtinguiſh what happens in the water we are examining? how are we to know, whether it is ſimple or whether it is compound?

Theſe queſtions, though very difficult at the time when chemiſtry was not furniſhed with all its reſources, may, conſidering our preſent knowledge, be now agitated;

tated; and we are hopeful of anſwering them in a ſatiſfactory manner. I obſerve, in the firſt place, that ſince the nature of the teſts is much better known than it was a few years ago, and their reaction upon the principles of the waters is much more fully appreciated, this is already a ground of ſtrong preſumption, that their uſe may be of much more utility than has hitherto been imagined. Among the great number of excellent chemiſts who have applied themſelves to the analyſis of waters, there have appeared none, except Meſſrs Baumé, Bergman, and Gioanetti, who have perceived that a greater part of them might be extracted than has as yet been done. It has been a long time the cuſtom, in examining mineral waters by teſts, to uſe very ſmall doſes, and to perform the experiment in glaſſes; the obſerved phenomena of precipitation are noted down, and the experiment is puſhed no farther. M. Baumé in his Chemiſtry has adviſed to ſaturate a certain quantity of a mineral water with the fixed alkali and the acids, to collect the precipitates, and to examine their nature. M. Bergman thought that we might judge by the weight of the precipitates of the quantity of the principles contained in the waters. Some other chemiſts have alſo employed this method, but always in ſome particular view; and no perſon has propoſed analyſing mineral waters by this means. To inſure ſucceſs, I am of opinion, that ſeveral pounds of a mineral water ſhould be mixed with each teſt, till the teſt ceaſe to precipitate the water. The precipitate is then to be allowed to collect for twenty-four hours in a veſſel cloſely ſhut; the mixture is to be filtrated: and by the known means, the precipitate remaining upon the ſiltre is to be examined after it has been weighed and dried. By this means, we ſhall diſcover completely the nature of the ſubſtance upon which the teſt has acted, and determine the cauſe of the decompoſition. We might follow a certain orin theſe operations, by firſt mixing the waters with the ſubſtances which are leaſt ſuſceptible of altering them; and thus advancing from theſe ſubſtances to thoſe which are capable of producing the moſt varied changes, and changes of the moſt difficult eſtimation. This is what I uſed to do in ſuch ſpecies of analyſis. After having examined the taſte, the colour, the weight, and all the other properties of a mineral water, I pour upon four pounds of this fluid as much lime-water; if no precipitate falls in twenty-four hours, I think myſelf certain that this water contained no diſengaged aërial acid, nor mild fixed alkali, nor earthy ſalts with baſe of aluminous earth or magneſia, nor metallic ſalts; but if a precipitate inſtantly or gradually forms, I filter the mixture, and examine the chemical properties of the depoſition. . If it has no taſte, if it is inſoluble in water, if it effervesces with acids, and if it forms with ſpirit of vitriol an inſipid ſalt almoſt inſoluble in water, I hence conclude that it is chalk, and that the lime-water attracted only the aërial acid diſſolved in the water. If, on the contrary, it is not copious, if it collects difficultly, if it excites no effervescence, if, with the vitriolic acid, it produces a ſtyptic ſalt, or a bitter one and very ſoluble, it is formed of magneſia or aluminous earth, and often by both. There is no need of being more explicit upon the means uſed to diſtinguiſh theſe two ſubſtances, as they ought to be very well known. I only add, that they might be repeated often enough, that no doubt of their nature may remain.

After their examination by means of lime-water, I pour upon four pounds of the ſame mineral water a gros or two of volatile cauſtic alkali; or I paſs through it ſome alkaline gas diſengaged by means of heat. When the water is ſaturated with it, I leave the mixture in a cloſe veſſel for twenty-four hours; then, if a precipitate is formed, which can ariſe only from the ſalts with baſe of iron, magneſia, or aluminous earth, I inveſtigate its nature by the different methods ſpoken of in treating of the action of lime. But the action of the alkaline gas being leſs to be depended upon than that of lime-wa-

water, which affects the ſame decompoſitions which it does, it is proper to obſerve, that we ſhould employ it only as an auxiliary; the reſults from which cannot be expected to be ſo accurate as thoſe given by the former teſt.

When the ſalts, with baſe of aluminous earth or of magneſia, have been diſcovered by means of lime-water or alkaline gas, the cauſtic mineral alkali ſerves to detect thoſe with baſe of lime; ſuch as ſelenite and calcareous marine ſalt. Therefore I precipitate ſome pounds of the water I am examining by means of this alkali diſſolved, till no farther turbidneſs is occaſioned, as it decompoſes the ſalts with baſe of aluminous earth as well as thoſe formed by lime; if the precipitate reſembles in form, colour, and quantity, that which is yielded by lime-water, it is to be preſumed that the water contains no calcareous ſalt; and the chemical examination of this precipitate generally confirms the ſuſpicion. But if the mixture is much more turbid than that with the lime-water; if the depoſition is more weighty, more copious, and collects more quickly; then it contains lime mixed with magneſia or aluminous earth. I ſatisfy myſelf by treating the depoſition with the different means already mentioned. It is known, that iron precipitated by the teſts at the ſame time with the ſaline earthy ſubſtances, is eaſy to be detected by its colour and taſte; and that the ſmall quantity of this metal, ſeparated by theſe proceſſes, is not capable of affecting the reſults.

It were uſeleſs to dwell upon the ſubſtances which the oil of vitriol, ſpirit of nitre, the gall-nut, alkalis, or lime, ſaturated with the colouring part of Pruſſian blue, when employed as teſts, might diſcover in the mineral waters. What has been delivered already about the general effects of theſe matters ought to ſuffice: give me leave only to ſay, that upon mixing them in great quantity with the waters, we may, by collecting the precipitates, diſcover more completely the nature and the quantity of

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their principles, as M. Bergman and M. Gioanetti have done.

I ſhall dwell longer upon the products given by the nitrous ſolutions of ſilver and of mercury when mixed with mineral waters. It is particularly with theſe teſts that it is of advantage to operate upon large quantities, to be able to determine the nature of the acids which theſe waters contain. The analyſis of theſe fluids will become complete by the knowledge of their acids, ſince theſe laſt are in them combined frequently with the baſes which the preceding teſts have diſcovered. The colour, the form, and the abundance of the precipitates formed by the nitrous ſolutions of mercury and ſilver, have completely indicated to chemiſts the nature of the acids to which they are owing. A copious weighty depoſition, which is inſtantly formed by theſe ſolutions, diſcovers the marine acid. If it is not ſo copious, white, and cryſtalliſed, with the lunar nitre; yellowiſh and irregular with mercurial nitre; if it collects but ſlowly, it is aſcribed to the vitriolic acid. However, as theſe two acids are found frequently in the ſame water, as an alkali and chalk alſo decompoſe theſe ſolutions, our reſults are uncertain when we refer only to the phyſical properties of the precipitates. We muſt then ſubmit them to a more thorough examination. For this purpoſe, the lunar and mercurial ſolutions ſhould be mixed with five or ſix pounds of the water which we wiſh to analyſe; the mixtures filtrated twenty-four hours after; the depoſitions dried, and treated *ſecundum artem.* Upon heating in a retort the precipitate made by the nitrous ſolution of mercury, the portion of this metal, united with the marine acid of the waters, volatiliſes in form of corroſive ſublimate or ſweet mercury: that which is combined with the vitriolic acid remains at the bottom of the veſſel, and is of a reddiſh colour. Theſe two ſalts may alſo be diſtinguiſhed by putting them upon a burning coal: the vitriol of mercury exhales ſulphureous vapours, and is coloured red; the marine ſalt remains white, and is volatiliſed without ſmell of ſulphur. Theſe phenomena ſerve alſo to diſtinguiſh the precipitates which might be formed by the alkaline ſubſtances contained in the waters, ſince theſe laſt exhale no ſulphureous odour, and are not volatile without decompoſition.

The precipitates produced by the combination of the mineral waters with the nitrous ſolution of ſilver, may be examined as eaſily as the preceding. The vitriol of ſilver being more ſoluble than the luna cornea, diſtilled water may be ſucceſsfully employed to ſeparate theſe two ſalts. Luna cornea is diſtinguiſhed by its fixity, fuſibility, and particularly its leſs decompoſibility than that of the vitriol of ſilver. This laſt, put upon coals, emits a ſulphureous odour, and leaves a calx of ſilver fuſible without addition. I do not ſpeak of all the proceſſes which chemiſtry might furniſh for diſcovering and ſeparating the two lunar ſalts juſt now mentioned; I think it ſufficient for me to mention ſome of them.

§ 6. *Examination of the Mineral Waters by diſtillation.*

In the analyſis of mineral waters, diſtillation is employed to find out the gaſeous ſubſtances united to them. Theſe ſubſtances are, either air, or aërial acid, or hepatic gas. To know their nature and quantity, we muſt take a few pounds of the mineral water, and put them into a retort, which they fill only to a half or two thirds; we muſt adapt to this veſſel a bent tube, which is to be ſunk in a veſſel full of mercury. The apparatus thus fixed, the retort is heated till the water be fully boiling, or till no more elaſtic fluid paſſes into the veſſels. When the operation is finiſhed, we ſubtract from the volume of gas obtained the quantity of air contained in the retort; the remainder is the aëriform fluid which was contained in the mineral water, whoſe nature we ſoon find by means of a lighted candle, tincture of turnſol, and lime-water. If it burns, and has a fetid odour, it is hepatic gas; if it extinguiſhes

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the candle, reddens turnſol, and precipitates lime-water, it is aërial acid: laſtly, if it ſupports combuſtion without inflaming, if it has no ſmell, nor alters turnſol nor lime-water, it is atmoſpheric air. It may happen that this laſt fluid is purer than atmoſpheric air; then we judge of its degree of purity by the manner in which it ſupports combuſtion. The proceſs, which is followed to obtain the gaſeous matters contained in the waters, is derived quite from modern chemiſtry. Formerly a moiſtened bladder was uſed, which was tied to the neck of a bottle containing a mineral water; the fluid was agitated; and by the ſwell of the bladder we judged of the quantity of gas contained in the water. Now we know that this method is not to be relied on; becauſe the water can part with all its gas only by ebullition, and becauſe the ſides of the moiſtened bladder alter the elaſtic fluid obtained. There is no need of obſerving, that by this proceſs only the diſengaged aërial acid is obtained which is contained in the mineral water we are examining; that we muſt carefully mark the phenomena which the water exhibits, in proportion as the gas is ſeparated: laſtly, that we ſhould diſtil a quantity of water, ſo much the leſs as it is ſhown to contain more gas, by its taſte, ſparkling appearance, and lightneſs.

§ 7. *Examination of Mineral Waters by Evaporation.*

EVAPORATION is generally conſidered as the ſureſt means of obtaining all the principles of mineral waters. It has been taken notice of already, and we repeat it again from the works of Meſſrs Venel and Cornette, that a long ebullition may decompoſe the ſaline matters diſſolved in the water; and for that reaſon we have directed the examination of them by teſts in large quantity. However, evaporation may be ſo far uſeful, when joined to analyſis by teſts, that it may be always conſidered as one of the principal means of analyſing waters; and that therefore the moſt proper method of conducting this proceſs ſhould be ſought after. The aim of this operation

ration being to collect the fixed principles contained in a mineral water, it is evident, that to know the nature and proportion of theſe principles, ſo much the more water muſt be evaporated as the water appears to be leſs charged. We ought to work upon twenty pounds at once when the water ſeems to contain much ſaline matter: if there is but little diſſolved, we muſt indiſpenſably evaporate a much larger quantity, ſometimes a hundred pounds. The nature and form of the veſſels for the evaporation is not at all indifferent. Thoſe of metal, except thoſe of ſilver, are alterable by water; thoſe of glaſs, of a certain thickneſs, are very ſubject to ruption; thoſe of glazed and well-baked earth the moſt proper, though the ſplitting of their covering coat ſometimes occaſions the abſorption of the ſaline matters. Thoſe of unglazed porcelain would be without contradiction the beſt; but their dearneſs is a conſiderable obſtacle to their uſe *. Different methods have been propoſed by chemiſts for evaporating mineral waters. Some have propoſed evaporating them to dryneſs in cloſe veſſels, to prevent the admixture of foreign ſubſtances, which may be floating in the air, with the reſiduum; but this operation is tedious. Others have directed a heat to be employed in their evaporation ſomewhat below the boiling point; imagining, that this degree of heat alters the fixed principles, and always carries off a part of them. This is the opinion of Venel and Bergman. M. Monnet, on the contrary, chooſes to boil the water; becauſe its motion prevents the admiſſion of foreign ſubſtances. M. Bergman gets rid

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* It were greatly to be wiſhed that a manufacture of common porcelain was raiſed, which might ſupply all the neceſſary veſſels to the kitchen, pharmacy, and chemiſtry. There is no need of a white, fine, precious porcelain; but of a very fine earth, with its ſurface poliſhed, of any colour, hard enough to reſiſt the heat and a ſudden heat and cold. We have long known how to make eaſily a good porcelain, which has at the ſame time not the beauty and whiteneſs ſo much valued, which raiſes the price conſiderably; now it is a porcelain of this kind which is wanted.

rid of this inconvenience, by covering the evaporating veſſel with a lid with a hole in the middle to give paſſage to the vapours. This laſt method greatly retards the evaporation, the ſurface of the fluid being conſiderably diminiſhed. It ought to be employed in the beginning till the vapours be ſtrong enough to diſperſe the powder. But the greateſt difference in the conduct of this experiment conſiſts in this, that ſome, copying Boulduc, ſeparate the ſubſtances which are depoſited as the operation goes on, in order to obtain each of the principles of the waters pure and detached. Some, on the contrary, urge the evaporation to dryneſs. We agree with M. Bergman, that this laſt method is more expeditious and more ſure; becauſe, whatever precaution we take in the firſt way, in order to ſeparate the different ſubſtances which are depoſited or which cryſtalliſe, they never are got pure; and we muſt always analyſe them farther: beſides, this method is never accurate, on account of the frequent filtrations, which occaſion great loſs; and in ſhort, it is very embarraſſing, and renders the evaporation very tedious. Waters, then, ſhould be evaporated to dryneſs; in which operation different phenomena are obſerved. If the water is charged with gas, bubbles appear in it upon the firſt impreſſion of the heat: in proportion as the aërial acid is diſengaged, a pellicle and depoſition is formed, ariſing from calcareous earth and ferrum aëratum. The cryſtalliſation of the ſelenite ſucceeds theſe firſt pellicles; and at laſt the marine and febrifugal ſalts cryſtalliſe in cubes at the ſurface, and the deliqueſcent ſalts are obtained only by conducting the evaporation to dryneſs: next, the reſiduum is weighed; it is put into a ſmall phial with three or four parts of ſpirit of wine: the whole is ſhaken; and after ſome hours reſt it is filtrated; the ſpirit of wine kept apart; the reſiduum which the ſpirit has not touched is dried with a gentle heat: after it is well dried, it is accurately weighed; and by the loſs the reſiduum has ſuffered, we know the quantity which it contained of calcareous marine ſalt and marine magneſia, which are very ſoluble in ſpirit of wine. We ſhall ſay more afterwards of the manner of aſcertaining the preſence of theſe two ſalts in the ſpirit.

Then the reſiduum, treated with the ſpirit of wine, and well dried, is waſhed with eight times its weight of cold diſtilled water; and after repoſe of ſome hours it is filtrated: the reſiduum is dried a ſecond time, and then boiled half an hour in four or five hundred times its weight of diſtilled water: it is again filtrated; and nothing remains but what is inſoluble in cold and boiling water. The former diſſolves the neutral ſalts, ſuch as Glauber's, marine, febriſugal, and Epſom ſalts: if nitre or alum were preſent, which rarely happens, they are likewiſe ſoluble in cold water. The boiling water, in conſiderable quantity, diſſolves but little of the ſelenite. There are, then, four ſubſtances to be examined after theſe different proceſſes are over: 1. The reſiduum inſoluble in ſpirit of wine and in water of different temperatures; 2. the ſalts diſſolved in the ſpirit; 3. thoſe ſeized upon by the cold water; and, laſtly, thoſe diſſolved by the boiling water. Let us proceed to the requiſite experiments for their examination.

1. The reſiduum, which has reſiſted the action of the ſpirit of wine and of water, perhaps compounded of calcareous earth, aërated magneſia, aërated iron, clay, and quartz; theſe two laſt ſubſtances are very rare, but the three firſt are very common: the deeper or lighter brown or yellow colour indicates the preſence of iron. If the reſiduum is of a whitiſh grey, it contains none of this metal. When iron is preſent, M. Bergman directs to moiſten it, and to expoſe it to the air, in order to ruſt it; then vinegar has no action upon it. In order to ſhow the means of ſeparating theſe different matters, let us ſuppoſe an inſoluble reſiduum, compoſed of the five ſubſtances which we have ſaid it might contain. We muſt begin by moiſtening and ex-

poſing it to the rays of the ſun: when the iron is very ruſty, the reſiduum is digeſted in diſtilled vinegar. This acid diſſolves the lime and magneſia; the ſolution is evaporated, and we get an acetous calcareous ſalt; which is diſtinguiſhed from acetous magneſia by its not attracting the air's humidity. Theſe two ſalts may be ſeparated by deliqueſcence, or rather by pouring into their ſolution ſome vitriolic acid. This forms ſome ſelenite which precipitates: if there has been an acetous magneſia, the Epſom ſalt, formed by the vitriolic acid, would remain diſſolved, and might be obtained by a well-conducted evaporation. In order to diſcover the quantity of magneſia and calcareous earth contained in the reſiduum, the ſelenite and Epſom ſalt, formed by pouring the vitriolic acid into the acetous ſolution, are ſeparately precipitated by the mild vegetable alkali, and the precipitate is weighed. When the chalk and magneſia has been ſeparated from the reſiduum, there remains only the clay, iron, and quartz. The iron and clay are both taken up by marine acid: the iron is precipitated by the Pruſſian alkali, and the clay by the fixed alkali; and theſe two ſubſtances are weighed to aſcertain their quantity. The matter which remains after the ſeparation of the clay and iron is generally quartzy; we aſcertain its weight and its nature by fuſing it with the fixed alkali by means of a blow-pipe. Such are the moſt accurate proceſſes recommended by M. Bergman to aſcertain the unſoluble reſiduum of waters.

2. We then take the ſpirit of wine, which has ſerved for the waſhing of the dry reſiduum of the waters: it is evaporated to dryneſs. M. Bergman directs treating it with ſpirit of vitriol, like the acetous ſolution mentioned above; but it is to be obſerved, that this proceſs ſerves to aſcertain only the baſe of theſe ſalts. In order to determine the acid united with the magneſia or lime, and ſometimes both, in this reſiduum, ſome drops of oil of vitriol muſt be poured in, which excites an efferveſcence,

fervefcence, and difengages the marine gas, known by its fmell and white vapour, when the falt which we examine is formed of marine acid. We may likewife aſcertain it by diffolving all the refiduum in water, and mixing with it a few drops of the folution of filver. With regard to the nature of the bafe, which is, as has been faid, either lime or magnefia, or both, their quantity and nature are likewife known by the vitriolic acid, as we have already obferved on the acetous folution.

3. The ley of the firſt refiduum of the mineral water, with eight times its weight of cold diſtilled water, contains the alkaline neutral falts; fuch as Glauber's, marine, febrifugal, mild fixed alkali, mild foda, and Epfom falt. Sometimes alfo a fmall quantity of martial vitriol is found. Thefe falts never are altogether in the fame waters. Glauber's falts and mild tartar are found but very rarely in the waters; but marine falt is frequently found with aërated foda: Epfom falt alfo occurs very often, and even in very confiderable quantity. When the firſt wafhing of the refiduum of a mineral water contains only one kind of neutral falt, it is very eafy to obtain it by cryſtallifation, and to afcertain its nature by its form and tafte, the action of the fire, and likewife by the teſts. But this cafe is very rare; and it is much more common that feveral falts are united in this ley. Their nature is then to be inveſtigated by a flow evaporation. Even this means does not always fucceed completely, however carefully this firſt ley is evaporated: each of the falts muſt be examined afrefh which are obtained at different times of the evaporation. It is for the moſt part the mild mineral alkali, which is confufedly depofited with the marine or febrifugal falts; thefe may be feparated by a procefs of M. Gioanetti. It confiſts in wafhing this mixed falt with diſtilled vinegar. This acid diffolves the mild foda: the mixture is dried, and wafhed afrefh with fpirit of wine, which is charged with the terra foliata mineralis, without touching the marine falt. The fpirituous folution

ſolution is evaporated to dryneſs, and the reſiduum calcined; the vinegar is decompoſed and burnt: we have then no more but the mineral alkali, whoſe quantity is exactly found.

4. The ley of the firſt reſiduum of the mineral water, with 400 or 500 times its weight of boiling water, contains only ſome ſelenite: of this we are certain, by making uſe of the very pure cauſtic volatile alkali; whilſt the cauſtic fixed alkali precipitates it in abundance. By evaporation to dryneſs, we aſcertain the quantity of the earthy ſalt which was contained in the water.

§ 7. *Of artificial Mineral Waters.*

The numerous proceſſes which we have juſt now deſcribed for the examination of the reſidua of the mineral waters after evaporation, are ſufficient to point out with the greateſt preciſion all the different ſubſtances which theſe fluids contain. A ſtep ſtill remains to be made to aſſure the ſucceſs of the analyſis; it is to imitate nature by ſyntheſis, and by diſſolving in pure water the different ſubſtances extracted by analyſis from a mineral water. If the artificial mineral water has the ſame taſte and weight, and exhibits with the teſts the ſame phenomena with the analyſed mineral water, it is the moſt complete and certain proof of the perfection of the analyſis. This combination has alſo the advantage of forming, at all times, in all places, and with ſmall expence, medicines as uſeful for the cure of diſeaſes as the natural waters, whoſe conveyance, and many other circumſtances, may tend conſiderably to alter their properties.

The moſt celebrated chemiſts think, that it is poſſible to imitate natural mineral waters. M. Macquer has obſerved, that, ſince the diſcovery of fixed air or aërial acid, and of its property of rendering many ſubſtances ſoluble in water, it is much eaſier to prepare artificial mineral waters. M. Bergman has taught us the way of compoſing waters perfectly to imitate thoſe of Spa, Seltz, Pyrmont, &c. He has told us, that they are very ſucceſsfully employed in Sweden. M. Duchanoy has publiſhed a work, in which he has given a ſet of proceſſes to imitate all the mineral waters employed in medicine. There is, then, all room to hope, that chemiſtry may be of important ſervice to the healing art, by furniſhing it with precious medicines, whoſe activity it may at pleaſure diminiſh or augment *.

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* As the Spa, Pyrmont, and Seltzer waters are much uſed in medicine, I have added the accurate analyſis of them given by M. Bergman, in his excellent treatiſe upon the ſubject of medicinal waters. According to this analyſis, the Swediſh cantharus, a meaſure which contains 100 geometrical cubic inches, yielded the following reſult:

Seltzer water.	Grains.
Aërated calcareous earth,	17
——— magneſia,	29½
Cryſtalliſed mineral alkali,	24
Common marine ſalt,	109½
	180

Spa water.	Grains.
Aërated iron, - -	3½
——— calcareous earth,	8½
——— magneſia, -	20
Cryſtalliſed mineral alkali,	8½
Common marine ſalt, -	1
	41½

Pyrmont water.	Grains.
Aërated iron, - - -	3¼
——— calcareous earth, -	20
Vitriolated calcareous earth, -	38½
Aërated magneſia, - -	45
Vitriolated magneſia, - -	25
Common marine ſalt, - -	7
	138¾

Artificial waters may be made to imitate the natural waters in every uſeful quality. The firſt part of the proceſs is, to impregnate the water with a ſufficient quantity of aërial acid, and then to add the other ingredients in their reſpective proportions. When thoſe artificial waters are prepared with proper attention to the proportion of the materials, they prove excellent ſubſtitutes for the natural ones. However, we muſt be cautious to employ ſalts purified by cryſtalliſation from any foreign matter; and to uſe iron in the moſt metallic ſtate, as the ſmalleſt tendency to ruſt renders it no longer ſoluble by means of the aërial acid.

LECTURE XLIV.

VEGETABLE KINGDOM.

Structure and Functions of Vegetables.

VEGETABLES are organiſed ſubſtances, which are confined to the ſurface of the earth, without either motion or ſenſibility. They are diſtinguiſhed by their appearance and conformation. They differ from minerals; becauſe they are nouriſhed by intuſſuſception, and becauſe they prepare the juices which are deſtined for the increaſe of their bulk. The phenomena they exhibit, depending upon their organiſation, are called *functions;* the principal is, their reproduction by means of ſeeds or eggs like animals.

Vegetables differ from one another, 1. In ſize: They are diſtinguiſhed into trees, ſhrubs, herbs, moſſes, &c. 2. In the place where they grow: Some grow in dry grounds, others in a humid ſoil; ſome in ſands, clays, waters, upon the ſurface of ſtones, or upon other vegetables. 3. In the ſmell, taſte, colour. 4. In their duration: plants live, are annual, biennial, &c. 4. In their uſe: they are employed as aliments or as medicines. A great number are employed in the arts, dyeing, &c.; others ſerve for the ornaments of gardens, &c.

§ 1. *Structure of Vegetables; Botanic Philoſophy.*

VEGETABLES, conſidered externally, are formed of ſix parts or organs, deſtined for particular functions: theſe parts are, the root, the ſtem, the leaf, the flower, the fruit, and the ſeed; each of theſe differ in their form, texture, ſize, number, colour, hardneſs, and taſte.

1. The root is concealed in earth, water, or in the bark of other vegetables. It is either tuberous, fibrous, or bulbous. It either hangs, as if on a pivot, or its direction is winding.

2. The ſtem, part of the root, and ſupporting the other parts: it is either ſolid or hollow, woody or herbaceous;

baceous; round, ſquare, triangular, or with two very acute angles. The ſtem comprehends the wood and the bark. The wood is diſtinguiſhed into wood properly ſo called, and into pulp: the bark is formed of the epidermis, of a veſicular texture and cortical layers. The ſtem is divided into branches.

3. The leaves are very variable in vegetables; *a*, in form; they are oval, round, lineal, ſagittated, lanceolated, &c.: *b*, in poſition upon the ſtem; being ſeſſile, petiolated, oppoſite, alternate, vertical, perfoliated, vaginal, &c.: *c*, in their margin; being entire, dentated, crenated, ſerrated, plaited, undulated, laciniated: *d*, in their ſimplicity or compoſition: the compound leaves are made up of ſmall ones; then they are either palmated or pinnated, *cum vel ſine impari*: *e*, in place; they are radical, caulinary, or floral: *f*, in colour, ſmell, taſte, conſiſtence, &c. Their uſe appears to be, from M. Ingenhouz's experiments, to abſorb the phlogiſticated air by their inferior ſurface, and to emit dephlogiſticated air by the ſuperior, when they are expoſed to the ſun. By this means the atmoſphere is renewed.

4. The flowers are parts deſtined to contain the organs of generation, and to defend them till parturition be accompliſhed; then they fall. In the flower two parts are diſtinguiſhed. The external parts are deſtined to envelope and to protect the internal, whoſe uſe is to reproduce the plant. The former comprehend the calyx and corolla; the calyx is external and green. Linnæus diſtinguiſhes ſeven kinds of it; to wit, the perianthium, the ſpatha, the ball, the covering, ſtrobilus, pappus, drupa. The corolla is what every body calls the flower or the coloured part: it is of one piece; and monopetal, or of ſeveral pieces, and polypetal. Upon the corolla Tournefort founded his ſyſtem. The pieces of the corolla are called *petals*. The organs, contained, and frequently hid, in the corolla, are the ſtamina and piſtils. The ſtamina are the male or generating parts; they are al-

moſt always more numerous than the piſtils. They are formed of a filament and anthera. This laſt, placed at the extremity, is a ſmall purſe, full of a generating powder: the piſtil is in the middle of the ſtamina; ſometimes it is in one flower, and ſometimes in another. On this account, ſome plants have been diſtinguiſhed into male and female. The piſtil is formed of three parts: the inferior part or ovarium, which contains the embryo, called in Latin *germen;* the filament, which is on the top of the ovarium or ſtile; and its extremity more or leſs dilated, called *ſtigma.* Linnæus, upon the number and reſpective poſition of the ſtamina and piſtils, has founded his ſexual ſyſtem. M. de Juſſieu has eſtabliſhed a ſyſtem from the inſertion of the ſtamina being either above or below the germen.

5. The fruit ſucceeds the flowers. Botaniſts diſtinguiſh ſeven kinds of fruits; the capſule, the ſiliqua, legumen, the ſtrobilus, which are dry; the drupa, the pomum, and bacca, which are ſucculent.

6. The ſeed differs greatly in form, appendices. It comprehends the corculum or little plant, the radicle, and the lobes.

Vegetables, conſidered internally, preſent five kinds of veſſels or organs, which are found in all their parts. 1. The common veſſels, deſtined for carrying the ſap. They are placed in the heart of plants and trees: they riſe perpendicularly; but they twiſt ſo as to form little holes or diviſions. 2. The proper veſſels, which convey the proper juices; the oily, the gummy, the reſinous juices. They lie under the bark: frequently they dilate into cavities or reſervoirs: they ſeem to be the excretory canals. 3. The veſſels for circulating the air which they receive from the atmoſphere. Upon cutting a young green branch, we perceive that they are ſpiral, and reſemble worms. They are frequently found filled with ſap. 4. The utricules, formed of ſacs, which contain the pith, and frequently a coloured part: they are placed in the middle of the ſtems.

5. The veſicular texture, exhibiting a ſet of ſmall cells, which are detached in a horizontal direction from the pith, and which paſſing through the ſap-veſſels, the cavities of which they fill, ſpread out below the epidermis, and form a net-work, ſtuffed up, ſimilar to the ſkin of animals. The veſicular texture of vegetables ſeems to correſpond with the cellular texture of animals.

§ 2. *Functions of Vegetables; Vegetable Phyſiology.*

All the organs of vegetables, of which we have juſt now given a ſhort deſcription, are deſtined to execute different motions, called *functions*. Theſe functions are, 1. The motion of the fluids, or a kind of circulation: 2. The alterations or changes of theſe fluids, which indicate a ſecretion: 3. The increaſe and evolution of the vegetable, which ſhows a nutrition: 4. The exhalation of different fluids elaborated in the different organs; and the inhalation of ſeveral principles contained in the atmoſphere, by means of the ſame organs: 5. The action of the air, and the uſe of this fluid in the veſſels of vegetables: 6. The motion made by ſome of their parts: 7. The kind of ſenſibility by which they know the contact of bodies that are uſeful to them, the light, &c.: 8. The different phenomena which ſerve for the reproduction of ſpecies, and which conſtitute the generation of plants.

Let us run over each of theſe functions in particular.

The principal fluid of vegetables, known by the name of *ſap*, is contained in particular canals, which are called *common veſſels*. Theſe veſſels, placed in the middle of the ſtems, and below the bark, are continued and prolonged from the root to the leaves and to the flowers. The ſap which they convey is a colourleſs fluid, more or leſs flat to the taſte, ſerves the ſame purpoſe with the blood of animals, of being converted into different juices for the nouriſhment and ſupport of the different organs. In the ſpring it is very copious; and its motion then appears from the evolution of the leaves and flowers. By ligature, as well as by all the phenomena of vegetation, it appears demonſtrated, that it mounts from the root to the ſtems and the branches. We do not know if it deſcends again towards the root, as ſome philoſophers have imagined. The valves, admitted in the common veſſels by ſeveral botaniſts, have not been demonſtrated, unleſs they chooſe to give this name to ſeveral filaments or hairs with which their internal ſide ſeemed ſtuck full to Tournefort and M. Duhamel. This irregular motion widely differs from the circulation of animals.

The ſap, conveyed in the utricules or proper veſſels, is elaborated in a particular manner. It gives riſe to different ſaccharine, oily, mucilaginous fluids, which iſſue out by an organic excretion, and whoſe evacuation ſeems to be of advantage to the vegetable, ſince it does not ſuffer from the great loſs which is thus frequently occaſioned. This alteration of the fluids, which is obſerved even in a remarkable degree in ſeveral organs, as in the nectarines at the extremity of the piſtil, in the pulp of the fruits, at the baſe of the calices, and of ſeveral leaves, correſponds exactly with the function which in animals goes by the name of *ſecretion*. M. Guetard has puſhed the analogy ſo far, as to deſcribe glands of ſeveral different forms at the baſe of the leaves of fruit-trees, and towards the extremity of the petals of certain flowers. It is this ſecretion which evolves the odorous principle, the colouring matter, the combuſtible ſubſtance: but it differs from the animal ſecretion in this, that this latter function entirely depends upon the organiſation of the glands, which elaborate the animal juices; whereas, in vegetables, the juices conveyed by the common veſſels are more expoſed to the contact of the air, of the light, and to the action of heat; and that their nature renders them ſuſceptible of undergoing by the action of theſe agents the motions of fermentation, which alone are capable of producing alteration upon them.

The ſap, by its remaining in the cavities of the utricles and of the cellular texture, thickens, and puts on a greater or leſs conſiſtence. This alteration renders it ſuſceptible of adhering to the ſides of the fibres, and of gradually increaſing their dimenſions. Such is the mechaniſm of the nutrition of vegetables, of their growth, and of the evolution of all their parts. It has a great reſemblance to the nutrition of animals. The veſicular texture and the utricles have the ſame ſtructure and the ſame uſes in theſe two claſſes of organic ſubſtances. They likewiſe penetrate all their organs; they eſtabliſh betwixt them an immediate communication; and both are the real foundation of nutrition.

It is a long time ſince botaniſts were convinced of exhalations from the ſurface of plants which ſpread in the air. The odorous ſpirit of the leaves and of the flowers forms round vegetables an atmoſphere, which is ſenſible to our organs, and which the contact of a burning body is ſometimes capable of inflaming; as is the caſe with the fraxinella. This exhalation ſeems to be an inflammable gas of a particular nature. Unhappy experience has even taught us, that ſeveral vegetables emit vapours mortal to animals which are expoſed to their action. Of this kind are the walnut and yew trees, and ſeveral others of the hot countries. M. Ingenhouz, in his experiments, found, that the leaves of all plants, expoſed to the ſun and to the light, mix with the atmoſphere an inviſible fluid, an air ſimilar to that procured from the calces of mercury, and improperly called *dephlogiſticated air*. Darkneſs entirely changes this property of the leaves, which then give only fixed air when they are deprived of the contact of the light. This beautiful diſcovery, firſt announced by Dr Prieſtley, demonſtrates a new property in vegetables, of purifying the air by communicating to it this portion of vivifying fluid, continually deſtroyed and abſorbed by combuſtion and reſpiration. But if vegetables continually emit vapoury fluids, which are only the laſt labour of vegetation, they likewiſe have the property of abſorbing ſeveral principles contained in the atmoſphere. The inferior ſide of the leaves abſorbs the humidity of the dew, according to M. Bonnet's experiments. Prieſtley's experiments have demonſtrated, that vegetables abſorb the gaſeous reſidua of combuſtion and reſpiration, ſince vegetation becomes more rapid and ſtrong in air altered by theſe two phenomena. Exhalation and inhalation, then, are much more extenſive in the vegetable kingdom than was imagined before the modern diſcoveries.

The gaſes abſorbed by vegetables, are conveyed into all their organs by means of veſſels called *air-veſſels;* which in their uſe and ſtructure approach to thoſe of inſects and worms. They enter the compoſition of the fluids as the air appears to do in the lungs of moſt animals; perhaps they contribute in a great meaſure to form the proper and eſſential ſalts of vegetables, theſe ſubſtances containing, as is well known, a great quantity of air. However, the air-veſſels are not ſolely deſtined to contain this fluid; they are found filled with ſap in the ſeaſons when this humour is very abundant; which makes them widely differ from the organs of reſpiration, ſo eſſential and ſo conſtant in a great number of animals.

It cannot be doubted, but that ſeveral parts of vegetables poſſeſs motion. In ſome it is ſo great, that it is ſenſible to the eye. Such are the motions of the ſenſitive plant, of the ſtamina of the opuntia, of the parietaria, &c. This motion ſeems to reſemble the function called in animals *irritability*, being occaſioned by the action of a ſtimulus, and having particular organs, that ſome botaniſts have compared to muſcular fibres. Upon this force alſo, does not the contraction of the woody fibres, occaſioned by the action of fire, depend? If that were the caſe, as M. Bucquet thought, irritability would be much longer inherent and durable in vegetables than it is in animals; ſince wood, however ancient it be, ſtill exhibits this phenomenon in a remarkable degree.

Can we refuſe likewiſe a ſort of ſenſibility to plants, when we ſee them turn their leaves and flowers to the ſun? when we obſerve that, when ſhut up in woody caſes, glazed, perforated, or ſimply, thinner in one part than in another, they conſtantly tend towards the tranſparent body, or to the opening which admits the light to paſs, or even to the ſide which is the moſt penetrable by this fluid, by its ſmall degree of thickneſs? or rather, ought not this degree of ſenſibility to be conſidered as the effect of the force of affinity of the tendency to combination ſubſiſting between vegetables and the light? It is fully demonſtrated, that this fluid evolves in plants, either by percuſſion or by combination, their colour, taſte, and combuſtible property; ſince plants raiſed in darkneſs are white, inſipid, aqueous, and contain nothing inflammable; whilſt vegetables, expoſed in hot climates, in the middle of the day, to the ſun's rays, acquire a conſiderable colour, and are charged with bitter and reſinous parts, and are ſingularly combuſtible. However ſtrong we may ſuppoſe this affinity, we cannot conceive how it ſhould be capable of exciting ſo great a motion in the branches and in the leaves of vegetables. It is then neceſſary to admit of a particular ſenſation; a feeling, it is true, very different from that of animals, by which vegetables are diſpoſed to chooſe the moſt bright places, or thoſe through which the light has the freeſt acceſs.

The means which nature employs to reproduce the ſpecies in vegetables, have great affinity to thoſe which ſhe makes uſe of for the production of animals. The ſexes, and their reunion, are requiſite in the moſt of plants. From the works of the celebrated Linnæus, it is found, that a remarkable analogy ſubſiſts between the organs deſtined to this function, in theſe two claſſes of organic ſubſtances. The ſtamina anſwer to theſe of the male, and the piſtil is compoſed of three parts, analogous to the genital parts of female animals. M. Decemet, phyſician of the faculty of Paris, has alſo imagined, that he diſcovered a ſtriking reſemblance in the external form of the parts of generation of the apocynum and other vegetables, and that of animals. The embryo is evolved by the action of the generating power; without which it is impoſſible to produce a new individual, as is every day obſerved with regard to birds. But without this analogy, which it would be uſeleſs to proſecute farther, vegetables being of a much more ſimple ſtructure than animals, and all their parts being compoſed of the ſame organs, each of them is capable of producing a new individual ſimilar to itſelf. This is the reaſon of the reproduction of plants by means of ſuckers, buds, ſlips, layers, and likewiſe of the alteration of the fluids by the operation of grafting, either natural or artificial. There is ſtill a new analogy between vegetables and this claſs of animals, which are produced by ſlips; as the polyps, cruſtaceous inſects, ſome worms, &c.

All the functions of vegetables, the whole of which give riſe to great relations between them and animals, are ſuſceptible of alterations which produce diſeaſes. Theſe diſeaſes, which depend moſt commonly either upon the abundance or defect of the ſap, as well as upon its bad qualities, are very analogous to thoſe of animals: their cauſes, their ſymptoms, their cure, depend abſolutely upon the great principles of medicine, and form a part of agriculture, little advanced, it is true, but ſuſceptible of great progreſs, when it ſhall be proſecuted upon the plan laid down by ſome famous writers on huſbandry; at the head of whom may be placed Meſſrs Duhamel and the Abbé Teſſier. The latter has thrown great light upon the diſeaſes of grains, in his Obſervations deſcribed in the volumes of the Royal Society of Medicine, and depoſited in part in the Royal Academy of Sciences.

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LECTURE XLV.

OF VEGETABLE JUICES.

THE humours of vegetables are of two claſſes; the common and proper juices. The firſt conſtitute the ſap, which is found in all plants. This fluid ſeems to ſupply the function of blood in vegetables. It is contained in the common veſſels: it flows naturally from their ſurface; but a greater quantity is got by inciſion. The ſap is not an aqueous fluid; it contains ſalts, extracts, and mucilages. When a certain quantity is wanted for the examination of its properties, or for medicinal uſe, the plant is bruiſed in a mortar, and ſtrained through a linen rag: if, in this way, the plant does not give out its juice eaſily, we ſubmit it to the preſs.

The ſucculent vegetables furniſh their juice by ſimple expreſſion: thoſe whoſe juice is viſcous or leſs abundant, require dilution with water; ſuch are borage and the dry aromatic plants. This juice being extracted by a ſtrong expreſſion, contains a portion of the ſolids of the vegetables which have been bruiſed by the peſtle: it muſt therefore be purified. The purification of the juices is effected, 1. By ſimple repoſe, when they are very fluid, as thoſe of purſlane and Barba Jovis. 2. By the white of an egg, which collects the feculent parts by means of coagulation, as is done to thoſe of borage, nettles, &c. 3. By ſimple heat, which coagulates and precipitates the filamentous parts, as M. Baumé directs in the treatment of juices containing volatile principles; ſuch as thoſe of the cochlearia, creſſes, &c. The phial containing the juice is plunged into boiling water, being ſtopped up with a perforated piece of paper: the juice, when it becomes clear, is drawn off; then it is immerſed into cold water, and filtrated. 4. By ſimple filtration for thoſe which are very fluid. 5. By the addition of ſpirit of wine, which coagulates the feculent parts. 6. By the vegetable acids, as preſcribed by the London pharmacopœia, for the juices of the cruciform plants.

Of Extracts.

THE juices of plants hold, in ſolution, ſubſtances which, when ſeparated from the aqueous vehicle, form kinds of extracts. Theſe ſubſtances are diſtinguiſhed into three ſpecies; the mucous extracts, the ſoapy, and the extracto-reſinous. The name of mucous extracts is given to thoſe which eaſily diſſolve in water, very ſparingly in ſpirit of wine, and which paſs to the ſpirituous fermentation; ſuch is the rob of gooſeberries, which is prepared by evaporating the juice of this fruit. The ſoapy extracts are characteriſed by their diſſolubility in water, and partly in ſpirit of wine, and by their diſpoſition to grow mouldy, rather than to paſs to the ſpiritous fermentation. The thickened juice of borage is an extract of this nature. Theſe are the extracts properly ſo called. The extracto-reſinous diſſolve in water and in ardent ſpirits: they are inflammable, becauſe they contain an oily principle; and they are altered in no way by the air. The inſpiſſated juice of the wild cucumber, called *elaterium*, is of this kind. Inciſions are made in the root of this plant; it is expreſſed; the juice is allowed to clarify itſelf, and then evaporated in a balneum mariæ to dryneſs.

In commerce, extracts of theſe three different kinds are prepared, by evaporating the juice of ſeveral plants: ſuch, among others, are,

a, The juice of acacia, brought from Egypt, by ſhaving the fruit of this tree, expreſſing its juice, and evaporating it by the heat of the ſun: the juice of the German acacia is prepared with the juice of prunes by a ſimilar proceſs.

b, That of hypociſtis, which is made like the preceding, with the fruits of this paraſite plant.

c, Opium, a very important medicine, whoſe nature ought to be completely known. It is extracted from the white poppy in Perſia. There flows through inciſions which are made in the green capſules, a white juice, which is dried into brown tears: that is the true opium. That in commerce is formed by preſſing theſe capſules after they are moiſtened with water: the juice is dried, and ſent away in flattened circular loaves, covered with leaves, and mixed with many impurities. In order to purify it, it is diſſolved in the ſmalleſt poſſible quantity of water by means of heat; the liquor is ſtrongly expreſſed, and evaporated in a balneum mariæ. This is the extract of opium. This ſubſtance contains a reſin, a ſolid eſſential oil, an odorous principle, poiſonous and narcotic, an eſſential ſalt, and a ſoapy extract. As the odorous, poiſonous, and narcotic part, is frequently nauſeous, the method of having the extract of opium free of it has been ſought for. M. Baumé, who has ſtrictly examined this medicine, volatiliſed this principle at the ſame time with the eſſential oil, and ſeparated likewiſe the reſin by a digeſtion of ſix months. M. Bucquet diſcovered, that this ſame extract may be obtained, calming and not narcotic, by diſſolving the opium in cold water, and evaporating the ſolution in a balneum mariæ. Our knowledge of the principles of opium goes no farther. M. Lorry has made ſome very excellent experiments upon the ſubject: he found that opium fermented, gave by diſtillation a calming, not poiſonous, water, which he employed with much ſucceſs. He obſerves, that the odorous principle of this medicine cannot be deſtroyed by any means.

When the plants, whoſe extracts we want, are dry and woody, we employ, in order to get their principle, maceration in water, infuſion, or decoction, according to the ſtate of the ſubſtances; maceration often ſuffices. Decoction extracts too much ſubſtance, and ſeparates the reſinous part: it forms a very impregnated thick fluid, frequently loathſome. Infuſion may ſuffice in all caſes: this is the opinion of the moſt celebrated chemiſts and phyſicians.

Extracts, differing from one another, are extracted by means of water, as thoſe which the thickened juices yield. Thus juniper-berries yield with water a mucous extract; Peruvian bark a ſoapy one, which is obtained in ſmall tranſparent and as if ſaline ſcales, if the ſolution is evaporated in very flat veſſels; from rhubarb an extracto-reſinous ſubſtance is obtained.

In commerce, alſo, extracts are prepared in great quantity by means of water: ſuch as,

a, The juice of liquorice root, yellow by the firſt infuſion, and black by the ſtrong decoction.

b, The terra Japonica, which is extracted from the infuſion of the ſeeds of a kind of palm: the infuſion is evaporaed, and the reſiduum is formed into flattened cakes. The terra Japonica in laboratories is purified by ſolution and evaporation.

From theſe conſiderations, it is eaſy to conceive, that the name of extract is given in general to all ſubſtances ſoluble in water, and ſeparated from this fluid by evaporation. However, as ſome eminent chemiſts, and particularly M. Rouelle ſenior, gave this name to a particular ſubſtance, which he conſidered as one of the ultimate principles of vegetables, it becomes a matter of importance to fix our ideas on this ſubject. There are only the ſoapy and extracto-reſinous extracts, which properly deſerve the name of extract. M. Rouelle diſtinguiſhed this laſt into extracto-reſinous and reſino-extractive. The extracto-reſinous burns only after it has been dried: it ſeems to contain more extract, properly ſo called, than reſin. The reſino-extractive burns much better than the former: it ſeems to contain more reſin than extractive ſubſtance. This clear diſtinction proves, that theſe two kinds are only mixtures of extracts in a different doſe with a reſinous principle. There are therefore no more extracts, properly ſo called: and this name ſhould peculiarly belong to the ſoapy matter. On this account, it is the properties of this ſubſtance which we muſt examine.

Pure extract, taken in the ſenſe of M. Rouelle, is a dry ſolid ſubſtance, coloured brown, or of a dirty green, which does not burn by itſelf, which emits much ſmoke, and in which is formed a greater or leſs quantity of eſſential ſalt. Its taſte is almoſt always bitter. It yields in diſtillation an inſipid phlegm: with a gentle fire this phlegm gradually becomes coloured and acid, according to M. Rouelle: for the moſt part, however, this phlegm is alkaline, as is obſerved in the Peruvian bark, the extract of borage. This volatile alkali is formed by the heat; then ſome empyreumatic oil paſſes over: the charcoal is light, contains ſome alkali, and almoſt always ſome neutral ſalts. The extract, when expoſed to the air, becomes mouldy, dries, or attracts the air's humidity, according to the nature of the ſalts which it contains. Theſe ſalts cryſtalliſe and ſeparate from the extractive part; frequently they are altered and entirely decompoſed. It diſſolves in water, and then forms a ſtrong infuſion. The acids decompoſe this ſolution as they do ſoaps, and occaſion a more or leſs oily precipitate. Metallic ſolutions alſo precipitate it, and are themſelves decompoſed. The proſecution of its chemical properties has been carried no farther; and hence it has been conſidered as a kind of ſoap.

In medicine, extracts are employed as aperient, deobſtruent, diuretic, ſtomachic remedies; and they are every day obſerved to produce the moſt excellent effects.

Of Eſſential Salts in general.

ESSENTIAL ſalts of plants is given as a name to the ſaline ſubſtances held in ſolution by their juices, or by the water of their infuſion. They are extracted by cooling theſe fluids, when evaporated, to the conſiſtence of ſyrup. As theſe ſalts are impregnated with mucilages and ſatty matters, they muſt be purified by means of lime and the whites of eggs. If theſe ſalts are acid, we ſhould not make uſe of lime, which neutralizes them, but of pure white clay in powder. After this firſt proceſs they are ſtill impure; they are then diſſolved in diſtilled water, and made to cryſtalliſe ſeveral times till they be white.

The eſſential ſalts of plants are of different natures; and ſhould be diſtinguiſhed into two claſſes.

Claſs 1. *Eſſential Salts.*

THE firſt claſs comprehends thoſe which reſemble the mineral ſalts. The principal kinds are, 1. The mild fixed alkalis, which are got from almoſt all plants by macerating them in acids, as demonſtrated by Meſſrs Margraaf and Rouelle junior: the vegetable alkali is the moſt common; the mineral is found in the marine plants. 2. Vitriolated tartar from the millefolium, old borragines, aſtringents, and aromatics, thymelæa, and pulp of olives. 3. Glauber's ſalt, from the tamariſk. 4. Nitre from the borragines, turnſol, tobacco, &c. 5. Sylvius's febrifugal ſalt from marine plants. 6. Selenite, from rhubarb, diſcovered by M. Model.

In vegetables, no doubt, ſeveral other ſalts might be found reſembling the mineral, if an accurate analyſis were made of a great number of plants. The volatile alkali, or rather mild volatile ſal ammoniac, has alſo been imagined to exiſt ready formed in the claſs of cruciform plants; becauſe theſe plants ſubmitted to diſtillation, yield, upon the firſt impreſſion of the heat, a phlegm containing a little of this ſalt in ſolution. On this account, the ancient chemiſts gave theſe the name of *animal plants*. But M. Rouelle junior has demonſtrated that it is not to be got ready formed in them; and that it is the reaction of theſe principles, occaſioned by the fire, which produces it. M. Baumé pretended, that the volatile principle of cruciform plants was merely ſome ſulphur.

Naturaliſts have entertained different opinions about the mineral ſalts which are found in plants. Some have thought that they have been conveyed from the heart of the earth by the water, and thus paſſed without alteration into the vegetables. Other have imagined, that vegetation formed theſe ſaline ſubſtances. It is certain, that two very different plants, as the borage and millefolium, growing in the ſame ſoil, furniſh each the ſame ſalt, which is proper to them; *viz.* the former nitre and the millefolium vitriolated tartar. One experiment alone, of which much has been ſaid, and which has not yet been made with proper accuracy, might decide this queſtion. It is this, To raiſe in a well-waſhed earth, plants which yield one kind of ſalt, as nitre, and to moiſten the earth with a ſolution of marine or of any other ſalt; if they ſtill furniſhed nitre and no marine ſalt, the concluſion might be drawn, that the ſalt in that ſtate does not enter the plants, and that the ſalt which is peculiar to them is formed by the operation of vegetation.

Claſs 2. *Of Eſſential Salts.*

THE ſecond claſs comprehends the ſalts particular to vegetables. Theſe truly eſſential ſalts are always formed of an acid united with an alkali and an oil. Frequently the acid is uncovered: ſometimes its taſte is covered by other ſubſtances; and therefore theſe ſalts ſhould be diſtinguiſhed into acid and ſweet.

§ 1. *Eſſential acid Salts.*

THE eſſential acid ſalts of vegetables are found in a great number of plants; and, in general, all thoſe of a ſouriſh taſte contain them: ſuch are ſorrel, acid fruits, lemons, oranges, &c. The ſalt the moſt known in this claſs, is that called in commerce *ſalt of ſorrel*, which is got from the oxalis. This plant is much cultivated in Switzerland and Germany. The falſe ſalt of ſorrel, or the ſalt of oxalis, is in white irregular cryſtals; it has a ſour taſte, and reddens the blue colours of vegetables. M. Baumé, who has examined it, diſcovered in it the following properties. It diſſolves very well in water, and it may be cryſtalliſed without loſing its acid; when heated in a crucible, it emits a ſharp acid ſmell; it bubbles up on burning coals; it becomes charry and kindles; it burns blue like ſpirit of wine; it leaves after its combuſtion a white ſalt, which, with ſpirit of ſalt, forms marine ſalts. Upon diſtillation, an ounce of this ſalt afforded three gros and a half of an acid liquor, which was colourleſs, ſmelling a little of marine acid. No oil came over. The reſiduum was fuliginous. This ſalt precipitates white the nitrous ſolution of mercury, as well as the acid does, which it gives to diſtillation. This acid, mixed with the nitrous, did not diſſolve gold-leaf. M. Bergman has placed the acid of ſorrel as a particular acid in the thirteenth cocolumn of his Table of Affinities. He differs from M. Baumé in ſome points, although he correſponds in the greateſt number, as we ſhall ſee; but he did not ſay whether it was the ſalt of ſorrel in commerce, or the true eſſential ſalt which he employed. His doctrine upon this ſubject is as follows: The ſalt of ſorrel is vegetable alkali, ſuperſaturated with a particular acid. M. Scheele has found a very good method of obtaining this ſalt: he mixed the acid of ſorrel, ſaturated with volatile alkali, with a ſolution of terra ponderoſa in nitrous acid: by dint of double affinity, the principles of theſe two compounds reciprocally changed their combination; and that of the terra ponderoſa with the acid of ſorrel is precipitated, becauſe it is very inſoluble. This precipitated ſalt is decompoſed by acid of vitriol, which has the ſtrongeſt affinity to it of any ſubſtance hitherto known: the acid of ſorrel ſwims above the ſpatum ponderoſum formed by this decompoſition, which may be poured off. This ſalt ſeems to reſemble the acid of ſugar more than it does that of tartar. It differs from both:

for, combined to ſuperſaturation with vegetable alkali, it forms the ſalt of ſorrel analogous to tartar; but it decrepitates and fuſes in the fire, turns a little black, and is ſuſceptible of being decompoſed entirely by aërated lime; properties not to be found in tartar: and farther, the vegetable alkali, combined with the acid of ſugar, reſembles neither tartar nor ſalt of ſorrel. The acid of ſorrel prefers lime to the alkalis; but it is ſtill doubtful, whether it does ſo to terra ponderoſa and magneſia: it decompoſes ſelenite, having more affinity with lime than the vitriolic acid has. If a ſtrong heat is applied to the acid of ſorrel it is deſtroyed; but it ſwells and blackens in a leſs degree than the acid of tartar. It gives to diſtillation a much more acid phlegm than tartar does treated in the ſame way. From theſe details, we ſee, that M. Bergman differs from M. Baumé only in admitting the vegetable alkali in this ſalt, whilſt the latter calls it the mineral. Perhaps it is the true ſalt of ſorrel which M. Bergman talks of.

All the acid ſalts in plants have not yet been examined, although we know a great number. That of citrons ſhould be ſeparated from its mucilage by reſt, and concentrated by means of freezing. It has been ſuppoſed analogous to the acid of tartar: however, in its more ſtrong taſte, it ſeems to reſemble rather that of ſorrel and of oxalis. Stahl ſays, that this acid, ſaturated with crabs-eyes, and digeſted upon ſpirit of wine, gradually aſſumes the nature of vinegar. It has been remarked by M. Bergman, that the ſparry, phoſphoric, arſenical acids, and thoſe of borax, ſugar, tartar, ſorrel, and citrons, reſemble each other in this, that when combined with earths they are almoſt inſoluble, and that they become ſoluble only by an exceſs of acid; whereas this property is not found in other acids. However, ſelenite and heavy ſpar, two earthy ſalts formed by the vitriolic acid, have almoſt no ſolubility.

The fruits, which are at firſt ſour, and which turn ſweet by ripening, yield a ſalt, whoſe acid is more covered than that in the preceding. This ſalt is in a medium between the ſtrong acid eſſential ſalts and thoſe which are quite ſweet; it reſembles the tartar of wine; it is got from apples, pears, quinces, tamarinds, &c. They have been carefully examined by M. Rouelle junior. We ſhall attempt a pretty full account of them when we come to the ſpirituous fermentation.

LECTURE XLVI.

§ 2. ESSENTIAL SACCHARINE SALTS.

THE eſſential ſaccharine ſalts are found in a great number of vegetables. The mapple, the birch trees, red beet, parſnips, raiſins, wheat, Turkiſh corn, &c. all contain ſome of them. M. Margraaf extracted them from the greateſt number of theſe vegetables.

The ſugar-cane *(arundo ſaccharifera)* contains the greateſt quantity of it; from which it is got with the greateſt profit. Theſe canes, when ripe, are ſqueezed between two iron cylinders placed perpendicular. The expreſſed juice falls upon a plate placed below. It runs into a veſſel, where it is boiled along with aſhes and lime; the ſcum is taken off; and thus boiled and ſcummed in three other veſſels; it then gets the name of ſyrup. Then it is again ſtrongly boiled with lime and alum: when ſufficiently boiled, it is poured into a cooling baſon; when it grows ſo cool as to be handled, it is put into barrels laid upon ciſterns, and having ſeveral holes ſhut up with canes. The ſyrup turns ſolid in the barrels, a portion runs into the ciſterns. The ſugar thus rendered concrete is yellow and thick. They refine it in the Weſt Indies by boiling, and then pour it into inverted earthen cones. The ſugar which cannot concrete, runs through holes into a pot placed below: it is called *thick ſyrup.* The baſe of the ſugar-loaves is taken off, and ſome white powder of ſugar ſubſtituted in its place, which is made hard by ſtriking. The whole is covered over with wetted pure clay. The water of the clay filtres through the ſugar, and carries along with it a portion of the mother-water of the ſugar, which flows thro' the holes, and is received into new pots. It is called *fine ſyrup*, being more pure than the firſt. A ſecond layer of clay is applied after the firſt is dry, and the water is allowed to filtre a ſecond time; and when the water has all run through, the loaves are carried to a ſtove to dry. In eight or ten days the loaves are broken, and the different ſugars thus formed are ſhipped for Europe, where they are refined to form the various kinds of it. The refining conſiſts in boiling the ſugar in lime-water along with ox blood, taking off the ſcum two or three times, filtering the liquor, and running into the form of loaves: then the loaves are covered with wet clay, and allowed to filtre. This is repeated till the ſugar be quite white; the loaves are carried to a ſtove, and after eight days covered with paper, and tied up for exportation. The ſyrups, which cannot be farther cryſtalliſed, are diſpoſed of under the name of *melaſſes*. All chemiſts have thought that theſe different operations ſeparated a fat matter from the ſugar, and rendered this ſalt ſuſceptible of cryſtalliſation. M. Bergman ſuppoſes the uſe of the lime to be, to carry off the exceſs of acid which prevents its aſſuming ſolidity. As it undergoes a ſtrong evaporation in theſe proceſſes, it turns into a granulated and irregular maſs, juſt as we have remarked happens at Goſlar in the preparation of white vitriol.

Sugar is formed of a particular acid united with a mall quantity of alkali, and changed by a great quanity of oily matters. It cryſtalliſes into truncated hexaëlral priſms, ſo as to form a kind of two-ſided pyramid. n this ſtate it is called *ſugar-candy*. It gives to diſtillaion an acid phlegm, and a few drops of an empyreunatic oil. A ſpongy light coal remains, containing ixed alkali. This ſalt is inflammable; laid upon burnng coals, it fuſes and bubbles up; it emits a pungent vapour; it turns of a brown yellow, and becomes a ſugar uſeful in coughs; it is very ſoluble in water; it gives it a great degree of conſiſtence; and forms a ſtrong ſaccharine mucilage, called *ſyrup*. This, diluted with water, is ſuſceptible of fermentation, and of giving ardent ſpirit.

M. Bergman has extracted an acid of a particular nature from all ſaccharine matters, and particularly from ſugar. We put into a retort one part of powdered ſugar with ſix parts of aquafortis: a gentle heat is applied. After the paſſing over of the red vapours, the ſolution is left to cool, and white needled cryſtals are precipitated, or they are priſms with four ſides terminated by two-ſided tops. The liquor poured off, and again heated with three or four parts of the ſame nitrous acid, yields by a freſh cryſtallization priſms of the ſame form. The ſame proceſs may be repeated upon the ſecond mother-water of theſe cryſtals. One ounce of ſugar yields about three gros of a priſmatic ſalt, which diſſolves in warm water, and may be cryſtallized by cooling to have it very pure.

The acid of ſugar has a very pungent acid taſte. Diluted with water, it forms a ſouriſh agreeable liquor. It reddens all the blue colours of vegetables. Expoſed to a gentle heat, it becomes opaque, as if effloreſcent; it turns into powder, and it loſes three-tenths of its weight by the evaporation of the water of its cryſtals. The water may be collected by diſtillation. Heated more ſtrongly, it fuſes; it turns brown; an acid phlegm paſſes over into the receiver, reſembling the ſalt itſelf in all its characteriſtic properties. A part ſublimes in form of a white cruſt; the retort contains almoſt no reſiduum. What remains is grey or brown, and comes, according to M. Bergman, only to about the fiftieth of the ſalt employed. A very conſiderable quantity of a gas is alſo produced: half an ounce of acid of ſugar gave M. Bergman one hundred cubic inches of a gas, conſiſting half of aërial acid, and half of inflammable gss, which burnt blue. M. l'Abbé Fontana, who repeated this experiment,

ment, obtained from an ounce of this ſalt four hundred and thirty-two inches of a gas; a third of which was aërial acid, and the reſt inflammable gas mixed with common air. Upon a repetition of the experiment, I had a reſult very nearly ſimilar to that of this laſt chemiſt. What is moſt ſingular, is, that the ſublimed portion, again diſtilled twice over, gives no coaly matter, and leaves only a whitiſh grey reſiduum. This ſalt, heated in an open fire, emits a very pungent vapour, and its reſiduum is quite white.

The acid of ſugar expoſed to the air effloreſces in length of time. Cold water diſſolves half of its weight of this ſalt, and boiling water its own weight. This ſalt cryſtallizes as the ſolution cools.

Acid of ſugar diſſolves clay, the baſe of alum. By evaporation the ſolution yields a yellowiſh, tranſparent, ſweet, aſtringent maſs, which attracts the air's moiſture, and reddens turnſol. This ſalt bubbles up when put into the fire; it parts with its acid, and leaves the clay brown. It is decompoſable by the mineral acids.

This acid combines with the ſaline-earthy and alkaline ſubſtances. It forms, 1. With terra ponderoſa, an inſoluble ſalt, yielding cryſtals of an acid taſte: hot water, which waſhes off the ſuperfluous acid, renders them opaque, powdery, and inſoluble. 2. With magneſia, a white powdery ſalt, decompoſable by the ſparry acid and terra ponderoſa. 3. With lime, a ſalt inſoluble in water, powdery, decompoſable by fire alone, on account of the immenſe attraction of theſe two ſubſtances, the acid of ſugar carrying off this baſe from all the other acids. M. Bergman on this account propoſes the acid of ſugar to detect the preſence and quantity of lime when contained in mineral waters, or combined with any acid. This ſalt turns the ſyrup of violets green.

It unites with the vegetable fixed alkali, and is ſuſceptible of cryſtalliſation when there is an exceſs of either of its principles. This ſalt, which is very ſoluble

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in water, is decompoſed by the action of fire and by the mineral acids.

Combined with two parts of fixed mineral alkali, the acid of ſugar forms not a very inſoluble ſalt, which diſſolves better in hot water, and turns the ſyrup of violets green.

With the volatile alkali an ammoniacal ſalt is formed, which cryſtalliſes by ſlow evaporation into quadrilateral priſms; which is decompoſed by fire, and furniſhes ſome mild volatile alkali, formed by the deſtruction of the acid of ſugar.

The acid of ſugar is ſoluble in the mineral acids. It turns the oil of vitriol brown, and is decompoſed by the ſpirit of nitre.

The acid of ſugar combines in general more eaſily with metallic calces than with the metals. It forms, 1. With white arſenic, cryſtals; priſmatic, very fuſible, very volatile, decompoſable by heat. 2. With cobalt, a powdery ſalt, of a clear roſy colour, not very ſoluble. 3. With the calx of biſmuth, a powdery white ſalt, very inſoluble in water. 4. With the calx of antimony, a ſalt in cryſtalline grains. 5. With nickel, a ſalt of a white or of a greeniſh yellow, inſoluble. 6. With manganeſe, a powdery white ſalt, which blackens by the fire. 7. With zinc, whoſe ſolution is accompanied with an effervefcence, a white powdery ſalt. 8. It diſſolves the calx of mercury, and reduces it to a white powder, which blackens by the contact of light: this acid decompoſes mercurial vitriol and nitre. 9. At firſt it blackens tin, which is afterwards covered with a white powder. The ſalt which it forms with this metal is of an auſtere taſte: it cryſtalliſes into priſms by a well-conducted evaporation. If in the evaporation a ſtrong heat be uſed, it yields a tranſparent maſs reſembling horn. 10. It tarniſhes lead, but diſſolves its calx better. The liquor, when ſaturated, depoſites ſmall cryſtals; which are alſo obtained by pouring the acid of ſugar into a ſolution of nitrous or marine lead, and likewiſe into a ſolution of ſaccharum Saturni. 11. It attacks iron filings, and produces ſome inflammable gas. This ſolution is ſtyptic. It yields priſmatic cryſtals of a greeniſh yellow, decompoſable by heat. Crocus martis, united with this acid, affords a yellow powder, reſembling that which is obtained by pouring the acid of ſugar into a ſolution of martial vitriol. 12. It acts upon copper, and entirely diſſolves its calx; the ſalt which it forms is of a clear blue, inſoluble: this ſalt may alſo be had from the precipitation of the vitriolic, nitrous, marine, and acetous ſolutions of copper, by means of the acid of ſugar. 13. The calx of ſilver, precipitated by the fixed alkali, diſſolves in ſmall quantity in this acid. The beſt method of preparing this ſalt, called by M. Bergman *argentum ſaccharatum*, is to precipitate the nitrous ſolution of ſilver by means of the acid of ſugar: a white depoſition falls, difficultly ſoluble in water, which turns brown by the contact of the light. 14. This acid has but a very inconſiderable action upon the calx of gold. 15. It diſſolves the precipitate of platina, occaſioned by the mineral alkali. This ſolution is a little yellow, and yields cryſtals of the ſame colour. Theſe are the phenomena mentioned by M. Bergman reſulting from the combination of the acid of ſugar with the metallic ſubſtances.

It might be imagined from the proceſs directed by M. Bergman for procuring the acid of ſugar, that this ſalt is owing to the nitrous acid employed in the operation. This learned chemiſt does not think this conjecture admiſſible; becauſe the acid of ſugar has none of the properties of the acid of nitre, and becauſe it differs from it in all its combinations. In fact, the nitrous acid does not ſeem to make a conſtituent part in the acid of ſugar; but, however, the great quantity of nitrous gas which exhales during the proceſs, announces the decompoſition of the ſpirit of nitre. Now, as, from M. Lavoiſier's experiments, the nitrous acid yields no gas, unleſs it part with the pure air which, combined with this gas, conſtitutes this acid, might we not imagine, that a part of this pure air combines with the combuſtible matter of the ſugar to form the acid which is extracted from it? We have ſeen, that in this way we might account for the production of the arſenical and dephlogiſticated marine acids.

M. Bergman aſcribes the cryſtalline form of the acid of ſugar to a portion of phlogiſton which remains combined with it. M. de Morveau, in an excellent note, taken notice of in the laſt paragraph of M. Bergman's Diſſertation upon the Acid of Sugar, has obſerved, that many acids become more fluid by the addition of phlogiſton, and that this property in all the acids depends upon the degree of their fuſibility.

Sugar is of immenſe uſe. It is an aliment, a great quantity of which is in danger of heating the conſtitution. Great uſe is made of it in pharmacy; forming ſyrups, lozenges, boluſes, &c. It ſerves well to ſuſpend in water reſins, oils, &c. It is uſed to preſerve the juices of fruits made into jelly: it may be conſidered even as a medicine, being expectorant, aperient, ſlightly tonic, and ſtimulant: there are likewiſe ſome facts recorded of ſome diſeaſes depending upon obſtructions being cured by the continual uſe of ſugar.

Of Manna.

THERE are ſome juices which flow from plants, and have a ſweet taſte. Manna and nectar are of this kind. Manna is produced by the leaves of the pine, of the holm, of the juniper, of the willow, of the fig, and of the maple trees. The aſh-tree, which is very plentiful in Calabria and Sicily, produces that of commerce. It flows naturally from theſe trees; but it is obtained in greater quantity by inciſions in the bark. What is collected upon the ſtraws or ſmall ſticks which are introduced into the artificial openings, forms kinds of ſtalactites, pierced in their middle; it is called *manna in tears*. Manna *en ſortes* flows upon the bark, and contains ſome impurities. The fat manna contains a great many ſtrange matters: it is formed from the impurities of the two former; it is always moiſt, and often changed. The taſte of manna is ſweet and inſipid. That which the larch-tree, very copious in Dauphiné, affords, and that of the alhagi, which grows in Perſia about Tauris, is of no uſe: this laſt is called *tereniabin*. Manna is ſoluble in water; it gives the ſame products to diſtillation as ſugar does. By means of lime and whites of eggs, a matter reſembling ſugar is extracted; and when treated with nitrous acid, it gives an acid ſalt, of the ſame nature with acid of ſugar.

In the doſe of an ounce, or of two or three ounces, it is uſed as a purgative; or in the doſe of a few gros, when diluted with water, if it is given as a deobſtruent.

Of Gums and Mucilages.

ANOTHER kind of proper juice is that called *gum* or *mucilage*. This is inſipid, ſoluble in water, to which it gives a thick and viſcous conſiſtence. This mucilage, when evaporated, becomes dry, tranſparent, and friable. Mucilage burns without flame; it gives to diſtillation a great quantity of acid phlegm, a little empyreumatic oil, and ſome volatile alkali: its coal, which is very bulky, contains vegetable fixed alkali.

There are three kinds of gum. 1. The gum of Pays, which flows from the apricot and pear trees, &c.: it is white, yellow, or reddiſh. 2. The Arabic gum, which flows from the acacia in Egypt and Arabia. The gum of Senegal is of the ſame nature. It is employed in medicine as a ſoftening relaxing remedy. It is uſed in ſeveral arts. 3. The gum tragacanth, which flows from the tragacanth in Crete; *tragacantha Cretica*. It is uſed like the preceding.

Mucilages of the ſame nature are extracted from a great number of plants. The roots of the wimote, linſeed, quinces, give out, by maceration in water, viſcous fluids, which, when evaporated, yield true gums.

All theſe ſubſtances, conſidered chemically, ſeem at firſt ſight to be bodies not very compound; ſince chemical experiments frequently preſent ſubſtances whoſe gelatinous form approaches to that of gums and mucilages. However, from theſe products of vegetation, which ſeem to ſerve the purpoſe of an excrementitious humour, water is extracted, ſome acid liquor, ſome aërial acid, an oily principle, and ſome fixed alkali, in the charry reſiduum. This reſiduum contains a fixed earth, whoſe nature is not yet known. Their inflammable part is not conſiderable, ſince they are not combuſtible. M. Bergman ſays, that he obtained from gums, treated with the nitrous acid, an acid ſimilar to that of ſugar.

LECTURE XLVII.

OILY JUICES.

OILS are proper juices, fat and unctuous, fluid or ſolid, inſoluble in water, combuſtible with flame, volatile in different degrees of heat; they are contained in proper veſſels or particular veſicles. They are diſtinguiſhed into fat and eſſential oils, into fluid and concrete oils. Theſe bodies are found in two ſtates in vegetables: either they are combined with other principles, as they are found in the extracts, mucilages, &c.; or they are free and detached. It is theſe we ſhall examine.

Chemiſts have thought a ſimple oily principle, like a primitive ſalt, exiſted. This oily principle, combined with different ſubſtances, and modified by theſe combinations, conſtitutes, according to them, the different kinds of oils which are obtained in the analyſes of vegetables. This ſimple and primitive oil is very fluid, volatile, colourleſs, inodorous; it burns with flame and fume. This fume condenſed has all the characters of coal: it does not unite with water: it is thought to be formed of an acid united with earth and phlogiſton. It is certain that the oils yield in their decompoſition in-

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flammable gas united to ſome aërial acid. They alſo contain a good quantity of water. The earth is in the ſmalleſt quantity, ſince they leave only a very ſmall quantity of fixed charry reſiduum. This theory of the oily principle ought to be conſidered merely as an hypotheſis. The oils are always formed by organic ſubſtances; and all the bodies which ſhow their characters in the mineral kingdom, owe their origin to vegetable or animal life. The oily juices of vegetables are diſtinguiſhed into fat and eſſential oils.

§ 1. *Of fat Oils.*

The fat oils are very unctuous; they have for the moſt part a mild inſipid taſte, without any ſmell: for their volatiliſation, they require a higher degree of heat than that of boiling water; and kindle only when expoſed to the heat requiſite for their volatiliſation. This is the uſe made of the cotton of lamps for kindling the fat oils. The oil is heated to the point of volatiliſation.

The moſt part of the oils are fluid, and require a very conſiderable cold for their converſion to a ſolid ſtate: ſome concrete with the ſlighteſt cold; others, again, are almoſt always ſolid; theſe are named *butters*.

The fat oils do not flow from the ſurface of vegetables: they are contained in the almonds, quinces, and emollient ſeeds. The cells which contain them being bruiſed, they come out by expreſſion.

The fat oils being expoſed to air, alter and turn rancid: their acid is evolved; they loſe their properties, acquire new ones, in which their nature approximates to the eſſential oils. Water and ſpirit of wine, by carrying off the evolved acid, deprive them of their ſtrong taſte, but never reduce them to their former ſtate.

They give to diſtillation an acid phlegm of a pungent odour, a light oil, a thick oil, and a great quantity of inflammable gas mixed with ſome aërial acid. They afford little charcoal. By the rediſtillation of theſe products, ſome phlegm and oil, becoming more and more light, is obtained. This oil is named *oleum philoſophorum*. The alchemiſts prepared it, by diſtilling ſeveral times a fat oil, with which they had impregnated a brick. It is not exactly known whence this decompoſition ariſes, although it may have been ſaid, that a fat oil can be reduced into a detached inflammable oil, an acid phlegm, air, and earth.

Water does not alter the fat oils; it purifies them by taking away a part of their mucilage, which likewiſe precipitates during combuſtion; and to which they owe their fermenting property, or that of becoming rancid.

The fat oils do not combine with the quartzy and vitreſcent earths: they afford with clay a ſoft paſte, which is employed in chemical manipulations under the name of *fat lute*.

By particular proceſſes they combine with magneſia, which reduces them to a ſoapy ſtate.

Lime unites with them, but not in a remarkable manner, when they are immediately combined.

The alkalis eaſily combine with the fat oils, and form a compound called *ſoap*.

In its preparation, the oil of olives or of ſweet almonds is triturated with mineral alkali, rendered cauſtic by lime; and hence called *ley of the ſoap-boilers*. The mixture does not thicken till it has ſtood a few days, and then forms the medicinal ſoap. That in commerce is made by boiling the ley with ſome altered oil: it is then white: orpiment is made uſe of to marble it. The green ſoap is made with the reſiduum of the olives after expreſſion and potaſh.

Soap is ſoluble in pure water. Heat decompoſes it, drives off phlegm, ſome oil, and ſome volatile alkali, ariſing from the decompoſition of the fixed alkali and oil. The coal contains much fixed alkali. Lime-water, M. Thouvenel ſays, decompoſes ſoap; and then a calcareous inſoluble ſoap is formed, which turns grumous. The acids poured upon ſoap diſengage its oil a little altered.

The volatile alkali does not unite but with difficulty with the fat oils; however, by a long trituration, the mixture acquires a little conſiſtence, and becomes opaque.

The fat oils unite with the acids, and form particular kinds of ſoap. Meſſrs Achard, Cornette, and Macquer, have ſtudied theſe compounds. M. Achard made them, by pouring gradually ſome fat oil upon vitriolic acid. By a continued trituration of this mixture, a brown maſs reſults, ſoluble in water and ſpirit of wine. The oil, which is extracted from it by means of the alkalis, is always more or leſs concrete, juſt like that which is obtained by diſtillation. M. Macquer here directs pouring the acid upon the oil; but he remarks, that an acid ſoap made in this way has little ſolubility in water. That which is prepared by the trituration of ordinary alkaline ſoap with oil of vitriol is more ſoluble.

Nitrous acid inſtantly conſumes the fat oils, and kindles thoſe that are dry. Thoſe which are not dry, cannot be kindled, unleſs by a mixture of ſpirit of nitre and oil of vitriol, as M. Rouelle ſenior has remarked in his Memoirs upon the Inflammation of oils, Académie, anno 1747.

The marine and aërial acids have but a very weak action upon the fat oils. The former, however, in its ſtate of concentration, combines, according to M. Cornette, with them to a certain degree.

The action of the other acids upon the fat oils is not known. The oils do not ſeem to combine with the neutral ſalts. Several of theſe, and particularly all the calcareous ſalts, decompoſe the alkaline ſoaps. In this decompoſition, particularly that effected by ſelenite and Epſom ſalt, which frequently are found united with mineral waters, the vitriolic acid unites with the fixed alkali of the ſoap, and forms Glauber's ſalt: the lime or magneſia combines with the oil, and forms a kind of very inſoluble ſoap, which ſwims in whitiſh lumps upon the water. This is the cauſe of the phenomenon exhibited by the waters, which curdle the ſoap without diſſolving it.

The action of inflammable gas upon the fat oils has not yet been examined.

The fat oils diſſolve ſulphur by means of a boiling heat; and this ſolution is of a deep red colour inclining to brown: it has a very fetid ſmell; it gradually depoſites ſome cryſtalliſed ſulphur. If this combination is diſtilled, the ſulphur is decompoſed, and not an atom of it is to be afterwards found. This experiment would merit a particular examination. Some ſulphureous gas is alſo obtained in this decompoſition.

The fat oils do not ſeem ſuſceptible of uniting with the pure metallic ſubſtances, except with copper and iron, upon which they exert a remarkable action: but they combine with their calces, and form thick concretes, which have a ſoapy appearance, as is obſerved in the preparation of ointments and plaſters. Theſe combinations have not yet been examined chemically; it is known only, that each of the metallic calces are reduced in the formation of plaſters, as the calx of copper in the emplaſtrum divinum, and the litharge in the unguentum martis. In docimaſia, or in the art of eſſaying, the fat oils are made uſe of in the reduction of the metallic calces. M. Berthollet has given an ingenious and ſimple proceſs for the formation of a combination of a fat oil with any metal, or for the formation of a metallic ſoap. It conſiſts of pouring a metallic ſolution into a ſolution of ſoap; the acid of the ſolution ſeizes upon the alkali of the ſoap, and the metallic calx precipitates with the oil, to which it gives its colour.

The fat oils diſſolve the bitumens, and particularly amber; but in this ſolution they require heat. They form kinds of fat varniſhes, which dry but with diſſiculty.

The fat oils ſhould be diſtinguiſhed into three kinds. The firſt comprehends the pure fat oils, which fix by cold, thicken ſlowly, form ſoaps with the acids, and kindle only by the addition of thoſe of nitre and vitriol. Such are, 1. Oil of olives; which is extracted from the pulp of this fruit ſqueezed between two ſtones, and then ſubmitted to the preſs in linen rags. That which comes out firſt is called *virgin oil;* that which is obtained from the reſiduum, wetted with water, is leſs pure, and depoſites a ley; that which is extracted from unripe olives is the omphacine of the ancients. Oil of olives congeals at 10 degrees above 0 of Reaumur's thermometer, and turns rancid only in about twelve years. 2. Oil of almonds, extracted without fire, turns rancid very quickly; it congeals at about 10 degrees below 0. 3. That of cabbage, which is extracted from the grain of a kind of collyflower called *colſat*. 4. That extracted from almonds, which come from Egypt and Arabia; it is very bitter and unodorous; it congeals eaſily.

The ſecond kind comprehends the dry oils, which thicken readily, do not fix by cold, which inflame by the nitrous acid alone, and which form kinds of reſins with vitriolic acid. Such are, 1. The oil of lin, which is extracted from the grain of roaſted lin by expreſſion. It is employed in fat varniſhing and in painting. 2. That of nuts, which ſerves the ſame purpoſe. 3. That of artichokes or of poppy ſeed, containing nothing narcotic, as is very well demonſtrated by M. l' Abbé Rozier. 4. That of hemp-ſeed, which is very dry.

In the third genus, we comprehend the concrete fat oils, or the butters. 1. That of cocao, extracted from the almonds of the cocao tree. Four kinds of cocao are diſtinguiſhed; the great and ſmall, berbeche, and that of the iſlands. The butter is extracted by torrefaction and boiling in water: it is purified by liquequefying it with a very gentle heat: it owes its concrete ſtate to an acid. 2. The cocoa furniſhes a ſimilar butter. 3. The wax of vegetables is of the ſame nature, only it has more ſolidity. It is extracted from the gall-nut in China: yellow, white, and green candles, are made of it, according to the method made uſe of to extract the wax. The berries of the birch and poplar trees may likewiſe yield a ſmall quantity of a ſimilar wax.

The uſe of the fat oils is great in the arts and in medicine.

As medicines, they ſerve as emollient, relaxing, calming, and laxative: ſome even are purgative, as the oleum ricini; which has alſo the virtue of killing and expelling the vermis ſolitaris. They enter a great number of compound medicines; as the balſams, the ointments, and plaſters; and they are uſed as aliments on account of the mucilage which they contain *.

§ 2.

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* Although M. Fourcroy ſeems to be of opinion that the fat oils have no power to act upon any of the metallic ſubſtances except copper and iron, there is much reaſon to believe that they are alſo capable of exerting their action upon mercury in a metallic ſtate. We have an inſtance of the combination of mercury with a fat of a ſimilar nature in the common preparation of mercurial ointment, where theſe two ſubſtances are intimately blended together by long friction in a marble mortar. In this ointment, the particles of the mercury do not merely ſeem to be interſperſed and diſtributed among the particles of the fat without any adherence or chemical union: on the contrary, the oily matter of mercurial ointment very quickly becomes rancid; and we know that rancidity is always the conſequence of the combination of oil with ſome other ſubſtance. When the mercurial ointment is old, if we rub a portion of it between two bits of paper, the whole of the oil is abſorbed, without leaving any globules of mercury viſible behind it: but when we treat mercurial ointment recently prepared in the ſame manner, we can very readily perceive a great number of metallic particles quite diſtinct. M. Baumé took equal quantities of mercurial ointment; one of which was new made, and the other had become ſlightly rancid by keeping. He kept both of them in a ſtate of liquefaction during eight days, in a degree of heat much below what could poſſibly decompoſe the fat. The new made ointment allowed three

drams

§ 2. *Eſſential Oils.*

The eſſential oils differ from the fat oils in the following characters: Their odour is ſtrong and aromatic; they are ſo volatile as to diſtil with the heat of boiling water; their taſte is very acrid; they are much more combuſtible than the former.

Theſe oils are found in almoſt all odorous plants. They are contained either through the whole of the

drams of mercury to ſeparate; the other, which was rancid, only one dram and a half. All thoſe obſervations do not allow us to doubt of the reality of the combination; they pointedly prove, that what we call the extinction of mercury in fat, is not purely the effect of a mechanical diffuſion, ſince thoſe two ſubſtances exert a ſlow ſpontaneous action upon one another, from which a more intimate union at length reſults. This is much confirmed, by obſerving the difference in colour and conſiſtence between old and new ointment. New-made ointment is of a very light colour, and extremely ſoft; while what has been kept for ſome time is much darker in colour, and much firmer in conſiſtence: A ſufficient proof of ſome change in the intimacy of their union.

We are in the next place to inquire in what ſtate the mercury unites with the fat, whether in form of a metal or in form of a calx. When old mercurial ointment is converted into a ſaponaceous compound by the addition of cauſtic alkali, there is always a quantity of fluid mercury ſeparated from the mixture, the fat forſaking the mercury to unite with the alkali. Mercurial ointment is alſo decompoſed by the action of ether upon it. When a ſmall quantity of good mercurial ointment is put into a flaſk, which is two-thirds full of ether and diſtilled water, and the mixture frequently ſhaken, the mercury ſoon begins to precipitate, carrying a ſmall portion of fat along with it, which gives the mercury the appearance of a calx; but this fat ſoon diſappears, and the mercury unites in the form of metallic globules, by ſimply drying it upon bibulous paper. By this analyſis we collect almoſt the whole of the mercury in a fluid ſtate.

In reviewing all thoſe facts carefully, it ſeems probable, that the mode in which mercury combines with fat, more reſembles the amalgamation of the metals with mercury, than their diſſolution in acids, as the mercury is taken up in a metallic ſtate, and not calcined; the fatty matter ſerving the purpoſe of a ſolvent to the mercury in the preparation of mercurial ointment, in the ſame way that mercury itſelf ſerves the purpoſe of a ſolvent to the other metals in the combination of the different amalgams.

plant, as in the Bohemian angelica; or in the root alone, as in the alder-tree, the oris, the white dictamnus, &c.; or in the ſtem, as in ſaunders, ſaſſafras, pines, &c.; or in the bark, as in the canella. Sometimes the leaves conceal it, as in the meliſſus, peppermint, wormwood. In other plants it is found in the calices of the flowers, as the roſe. The petals of camomile and of the orange are filled with it. At other times it is fixed in the fruit; as in cubebs, pepper, juniper berries: And, laſtly, many vegetables contain it in their ſeed; as nutmeg, aniſe, fennel, and moſt of the umbelliferous plants.

They differ from one another, 1. In the quantity, which greatly varies according to the ſtate or age of the plant. 2. In the conſiſtence. There are ſome very fluid; as thoſe of lavender and rue. Some congeal by cold; as that of aniſe, fennel: Others are always concrete; as thoſe of roſes, parſley, and alder. 3. In the colour: Some have none; ſome are yellow, as that of lavender; of a deep yellow, that of canella; blue, that of camomile; aqua marine, that of mille-pertuis; green, that of parſley. 4. In weight: Some ſwim upon water, as moſt of our own country oils: others go to the bottom; as that of ſaſſafras and cloves, and moſt of thoſe from foreign plants. This property, however, is not conſtant, relatively to the climate; as the eſſential oils of nutmeg, mace, pepper, are lighter than water. 5. In ſmell and taſte: This laſt property is often very different in the eſſential oil from what it is in the plant; for inſtance, pepper gives a ſweet oil, and wormwood a bitter.

Eſſential oils are got, 1. By expreſſion, from the citron, bergamot, orange, cedar trees, &c. 2. By diſtillation. The plant is put into an alembic of copper along with ſome water; the water is made to boil; the oil paſſes over with the water, from which it is ſeparated by means of a proper veſſel.

The eſſential oils are adulterated, either by the fat oils, and the fraud is then detected by trying if they ſtain paper; or by the oil of turpentine, which is known by its ſtrong ſmell, and which remains after the evaporation of the eſſential oil; or by means of ſpirit of wine; then water, by rendering them turbid, diſcovers the fraud.

The eſſential oils loſe their colour by a gentle heat; and as they are very volatile, the fire cannot decompoſe them. By heating them in cloſe veſſels, a great quantity of inflammable gas eſcapes. When they are heated with the contact of air, they kindle readily, and emit a very thick fume, which condenſes into a charry matter, very light and fine: they leave, after inflammation, very little coal, being ſo volatile, that the charry part riſes in the volatiliſed portion.

Expoſed to the air, they thicken as they grow old, and appear like a reſin. Needled cryſtals are depoſited, reſembling thoſe of ſublimed camphor, which Geoffrey junior obſerved in that of motherwort, marjoram, and in that of turpentine. Their ſmell alſo approaches to that of camphor, according to the ſame obſerver, Acad. 1721, p. 163.

They unite difficultly with lime and the alkalis: the acids alter them; the concentrated vitriolic acid changes them into bitumens; and if it is weak, it converts them into kinds of ſoaps. They kindle into flame with the nitrous acid, and the marine acid makes them into ſoaps.

They have no action upon the neutral ſalts. They eaſily combine with ſulphur, and form compounds called *balſams of ſulphur*; in which the ſulphur is ſo changed, that it never can be wholly ſeparated, nor its preſence ſcarce made to appear.

Mucilages and ſugar render them ſoluble in water *.

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* The eſſential aromatic oils have not the ſmoothneſs, ſlipperineſs, and unctuoſity of the expreſſed oils. They are all volatile in the heat of boiling water, or nearly in that degree of heat; and the ordi-

In medicine they are employed as cordial, ſtimulant, antiſpaſmodic, emmenagogue, &c. Exhibited externally, they prove frequently antiſeptic, and retard the progreſs of carious bones.

ordinary method of obtaining them is, to macerate the plant in water, and afterwards to ſubject the whole to diſtillation, when the volatile oil ariſes along with the vapour of the water. The only purpoſe of adding the water is to give an eaſy method of adjuſting the heat; for if the vegetable was to be put into the ſtill without any addition of water, ſome parts would be ſcorched and deſtroyed before others were ſufficiently warmed to exhale the eſſential oil, as it is not poſſible to diſtribute the heat equally without the aſſiſtance of a fluid medium. The water which comes over is impregnated with the taſte and flavour of the oil, for water is capable of diſſolving a ſmall portion of eſſential oils; and in this ſtate is called a *ſimple diſtilled water*. Many ſuch are prepared for common uſe from roſes, cinnamon, peppermint, and other aromatic plants. They all owe their virtues to a quantity of the eſſential oil of the vegetables; as we know they may be prepared in a different manner, merely by mixing ſome eſſential oil of the vegetable with pure water, by agitation. The ſolution of theſe oils in water does not ſeem to be very perfect, as there is commonly ſome degree of milkineſs and want of tranſparency; which is proof ſufficient of an imperfect ſolution. This diſſolving power of water diminiſhes the yield of oil to a certain degree, ſince we do not yet know of any way by which it can again be ſeparated. But this inconvenience is not very great in practice, as the water is ſoon ſaturated, and will diſſolve no more; ſo that all the redundant oil ſeparates from the water, and either ſinks to the bottom or riſes to the top, according to the relative ſpecific gravity. If therefore the pure oil be the object of our purſuit, we have only to pour water, fully ſaturated by a former diſtillation, upon a freſh parcel of materials, when the whole of the oil may be eaſily collected without loſs, as no more can be diſſolved in the water. Some vegetables are ſo tender, that the ſimple maceration in water impairs the delicacy and fragrance of their odours. In ſuch caſes, the vegetable is only expoſed to the ſteams of boiling water, which penetrate every where, and carry the eſſential oil along with them. To accompliſh this end, we extend a piece of hair-cloth over the water of a common ſtill, and lay the vegetable upon it, and raiſe the heat to the degree which we wiſh. For as ſome vegetables do not require a boiling heat, but are greatly injured by expoſure to one ſo great, we can by this contrivance temperate the heat at pleaſure, and employ the exact degree which is requiſite for the particular plant, and never allow the fire to excite a greater. Roſemary and lavender, diſtilled with this precaution, give over an oil much ſuperior in fragrance to what is obtained by a boiling heat.

Spirit of wine diſſolves the eſſential oils more thoroughly than a watery menſtruum; and as the ſpirit alſo riſes in a lower degree of heat, all the aromatic properties of the plant are extracted in higher perfection. There are, however, but a ſmall number of plants which are volatile in the heat which raiſes ſpirit of wine; ſo that, if we wiſh the ſpirit to be impregnated with ſuch oils, we either diſſolve directly ſome oil which we have obtained by a different proceſs; or we add the ſpirit to the ſimple water, which, in the courſe of diſtillation, carries off the aromatic odorous principle; and thus we obtain a ſpirituous impregnation of the eſſential oil.

The aromatic parts of vegetables are contained in ſeparate ſpaces, diſtinct from the general matter of the plant. A good microſcope will ſhow a number of ſhining particles compoſed of this matter; and if theſe be all carefully picked out, the plant will no longer yield a ſingle drop of aromatic oil.

Some chemiſts have ſuppoſed that the lily, violet, jeſſamine, narciſſus, hyacinth, and other very delicate flowers, derived the fragrance of their odour from the preſence of ſome principle different from the eſſential oil, becauſe thoſe chemiſts had always failed in their attempts to collect the oil in any conſiderable quantity. This opinion is, however, ſo far erroneous, that Neuman ſaw eſſential oils obtained from all thoſe plants in different parts of the warmer countries of Europe. The product was indeed extremely trifling; ſo that the very powerful effluvia of theſe flowers muſt ariſe from the extreme volatility, pungency, and diffuſive nature of their eſſential oils. And in this conſiſts the only difference between them and other aromatic vegetables.

As it is ſometimes difficult to collect a large enough quantity of rare flowers to prepare oil from them, ſome have propoſed to ſalt the aromatic parts, and keep them till a ſufficient collection be made. When this advice has been followed with roſe-leaves, the diſtilled water was found to contain a ſmall portion of marine acid; which appeared from the effect of the roſe-water in diſturbing the nitrous ſolution of ſilver.

Another practice is recommended in particular caſes where a ſlight degree of fermentation increaſes the produce, or in ſome meaſure ſeems to create the oil. To ſuch plants a little yeſt of ſome kind is added, to promote the fermentation. The veronica, a plant which yields ſcarcely any oil when in a freſh ſtate, will give over a great deal by being allowed to ferment for ſome days. Whether this incipient proceſs only ſerves to extricate what was already formed, or really alters the combination of the different principles, is a matter which has not yet been fully examined.

LECTURE XLVIII.

Of CAMPHOR.

CAMPHOR is a white, concrete, cryſtalline ſubſtance, of a ſtrong ſmell and taſte, which approaches to the eſſential oils in ſome of its properties, but widely differs from them in others.

This ſubſtance is extracted from a kind of laurel, growing in China, Japan, and in the iſlands of Borneo, Sumatra, Ceylon, &c. The tree which produces it ſometimes contains ſo great a quantity, that cleaving it is ſufficient to obtain very large and very pure tears. It is obtained, however, by diſtillation. The roots or other parts of the tree are put into an iron alembic along with ſome water; they are covered with a head, in which ſome rice-ſtraws are placed; and the whole is heated. The camphor ſublimes in ſmall greyiſh grains, which are united into larger pieces. This coarſe camphor is very impure. The Dutch purify it by ſublimation in kinds of balloons, by the addition of an ounce of lime to the pound of camphor. It may alſo be extracted from the roots of the canella tree, zedoary, thyme, roſemary, ſage, and from all the labiated ones, either by diſtillation or decoction, as Meſſrs Neuman and Cartheuſer have remarked; but the camphor is in very ſmall quantity, and it always has a ſlight ſmell of the plant from which it was extracted. This ſingular ſubſtance ſeems to be found in combination with the eſſential oils of theſe vegetables, ſince Geoffroy obſerved that theſe oils depoſited camphorated needles.

Camphor is much more volatile than the eſſential oils, as it ſublimes with the gentleſt heat; it cryſtalliſes into hexaëdral laminæ, adhering to a filament. If it is briſkly heated, it fuſes before it is volatiliſed. It ſeems to be incapable of decompoſition in this way: however, if it is ſeveral times diſtilled, it yields a reddiſh and manifeſtly acid phlegm; which indicates, that by a frequent repetition of this proceſs it might be decompoſed.

its own temperature is ſufficient to volatiliſe it: expoſed to the air, it diſſipates entirely; included in a veſſel, it ſublimes in hexagonal pyramids, or into polygonal cryſtals; which were obſerved and deſcribed *anno* 1756 by M. Romieu, (Acad. 1756, p. 443). It emits a ſtrong ſmell, unſupportable by ſome perſons: it kindles very rapidly, burns with a great ſmoke, and leaves no charry reſiduum.

It does not diſſolve in water; it communicates to it its ſmell; it burns at its ſurface. M. Romieu obſerved, that ſome little pieces of camphor, of a third or of a fourth of a line in diameter, put in a glaſs of pure water, are moved, turn round, and diſſolve in half an hour. He ſuſpects that this motion is an effect of electricity; and he remarks, that it ceaſes when the water is touched with a conductor, as a wire of iron; and, on the contrary, that it continues when touched with an inſulated body, as glaſs, reſin, ſulphur, &c.

The earths, ſaline-earthy, and alkaline ſubſtances, exert no action upon camphor; the effect, however, of the cauſtic alkalis has not been tried.

The acids diſſolve camphor when they are concentrated; oil of vitriol diſſolves it by means of heat: this ſolution is reddiſh. The nitrous acid diſſolves it without noiſe: the ſolution is yellow. As it ſwims above the acid as oils do, it has been called *oil of camphor*. The marine acid in the ſtate of gas diſſolves camphor, and likewiſe the ſulphureous and ſparry gaſes. If ſome water is added to theſe ſolutions, they grow turbid; the camphor ſeparates in flocci, which ſwim a-top, and have undergone no alteration. The alkalis, the ſaline-earthy, and metallic ſubſtances, likewiſe precipitate theſe ſolutions.

The neutral ſalts have no action upon camphor. The effect of ſulphur and the bitumens is not known, though it is probable that they are capable of uniting with it.

The fat and eſſential oils diſſolve camphor by means of heat. Theſe ſolutions, when cool, gradually depoſite cryſtals, like vegetation, reſembling thoſe which are found in the ſolutions of ſal ammoniac; that is, made up of a moderately ſized ſide, to which very fine filaments, placed horizontally, adhere. Theſe kinds of plumage, viewed with a microſcope, are very beautiful and regular. This nice obſervation is owing likewiſe to M. Romieu, (Acad. 1756, p. 448). We ſhall afterwards take notice of the ſolution of camphor in ſpirit of wine, which is much better known and much more uſed than the preceding, that it exhibited a ſomewhat different cryſtalliſation, which he obtained by a particular proceſs.

We muſt not forget to obſerve, that a phyſician, as illuſtrious for his extenſive knowledge as for his great conception of the action of medicines, M. Lorry, conſiders camphor as a principle very diffuſed in vegetables; and he places its ſpiritus rector at the head of a claſs of very ſtrong ſmells, to whoſe effects upon the animal-œconomy all chemiſts and phyſicians ought to attend.

Camphor is one of the moſt powerful remedies which phyſic poſſeſſes. Applied to inflamed tumours, it ſoon diſſipates them. It is employed as an antiſpaſmodic and antiſeptic in contagious diſeaſes, in malignant fevers, and in all diſeaſes accompanied in general with nervous and putrid affections. In France it is adminiſtered ſcarcely in the doſe of a few grains; in Germany they augment the quantity to ſeveral gros a-day. It is alſo important to know, that camphor calms ardors and pains in the urinary paſſages, often as if by enchantment. Triturated with yolks of eggs, ſugar, gums, or in the ſtate of oil of camphor, it is put into ſome convenient drink. The ſurgeons employ the *ſpiritus vini camphoratus*, to be deſcribed afterwards, in external gangrenes, whoſe progreſs it frequently retards and ſtops.

Spiritus Rector.

Boerhaave has given the name of *ſpiritus rector of plants* to their odoriferous principle; only very little is known about the properties of this ſingular ſubſtance, altho' ſo intereſting in its effects upon the animal œconomy. The ſpiritus rector ſeems to be very volatile, very diſſipable, and attenuated; it is perpetually flying off from plants, and forms round them an odorous atmoſphere, which is diffuſed to a greater or leſs diſtance. All plants differ from one another in the quantity, power, and nature of this principle. Some are abundantly provided with it, and even loſe it only partially upon exſiccation; ſo that it hence appears to poſſeſs a certain degree of fixity; ſuch as, in general, the odorous woods, and all the odorous parts of vegetables, dry and woody. In others it is ſo diſſipable and ſo volatile, that though they have a ſtrong ſmell, the principle is with difficulty fixed. And there are ſome plants whoſe ſmell is inſipid, and not very ſenſible: they have been named *inodorous;* theſe having only the ſmell of an herb, their principium rector has been called *herbaceous.*

The ſlighteſt heat is ſufficient to diſſipate the ſpiritus rector from plants. To obtain it, we muſt diſtil the plant in a balneum mariæ, and receive its vapours in a cold head, which condenſes them, and makes them run in a liquid ſtate into the receiver. The product is a limpid water charged with ſmell, which has been called *eſſential* or *diſtilled water.* This liquor ſhould be conſidered as a ſolution of the odorous principle. As this principle is more volatile than the liquid in which it is diſſolved, if the ſpiritus rector is heated, it gradually loſes its ſmell, and becomes inſipid: expoſure to air produces the ſame alteration: it depoſites very light, apparently mucilaginous, tufts, and even acquires a mouldy ſmell.

The principle of odour unites with the oily juices, and alſo ſeems to make one of the elements of the eſſential oils; ſince, 1. Theſe always contain it. 2. The plants which have a tenacious odour conſtantly yield more eſſential oil than thoſe do, whoſe odour is volatile, and which yield frequently none at all. To retain the ſpiritus rector of theſe laſt, as of the jeſſamine, tuberoſe, &c. it muſt be combined with the fat oils. The flowers are put into a tin cucurbit with cotton, impregnated with ſome oil of benzoin: the flowers and cotton are laid alternately; the cucurbit is ſhut up, and expoſed to a gentle heat. The ſpiritus rector is diſengaged, and combines with the oil, and fixes itſelf in a durable manner. 3. The plants which have no ſmell never yield a drop of eſſential oil. 4. The vegetables from which the ſpiritus rector has been extracted in a balneum mariæ yield no more of this kind of oil, unleſs they ſtill retain a little of the ſmell; in this caſe they yield, too, only a very ſmall quantity. 5. An eſſential oil which has loſt its ſmell eaſily regains all its properties, when it is diſtilled upon the freſh plant from which it was at firſt extracted.

The action of the ſaline ſubſtances upon the ſpiritus rector has not been examined.

The nature of this principle is not identical, and it ſeems to differ according to the genera of plants to which it belongs. M. Macquer thinks with Boerhaave, that it is in general compoſed of an inflammable ſubſtance and a ſaline matter; but he obſerves, that it ſometimes partakes more of the ſaline nature, whilſt in other plants it approaches more to the oily matters. The ſpiritus rector of the cruciform plants appears to him to be ſaline, and he gives it the characters of being pungent and penetrating without affecting the nerves. That, on the contrary, which is inſipid or ſtrong, but without being pungent, and which affects the nerves ſo as to produce or allay the fits which depend upon their impreſſion, as thoſe of the aromatic and narcotic plants do, participates greatly of the oily nature, according to this celebrated chemiſt. Some facts ſupport this aſſertion. The fraxinella emits an odour, which forms an inflammable atmoſphere round the plants, which an ignited combuſtible body kindles; then this vapour burns from top to bottom, along the ſtem which ſupports the flowers. The ſpiritus rector of the fraxinella ſeems then to be of an oily nature. M. Venel, a chemiſt of Montpelier, and ſcholar of Rouelle, extracted from the cheſnut, with a gentle heat, an acid ſpiritus rector: and the late M. Roux profeſſor of chemiſtry, who examined this product, found that it does not redden the blue colours of vegetables, but that it ſaturates the alkalis. The nature of the ſpiritus rector of cruciform plants is not determined. Some ſuppoſe it acid, others alkaline. It ſeems from the works of Meſſrs Deyeux and Baumé, that ſulphur is found combined with the odorous principle of the antiſcorbutic plants. As to what remains. we have already taken notice of theſe beautiful diſcoveries elſewhere.

There are ſtill two important reflections to be made upon ſpiritus rector. The firſt is what M. Macquer very properly ſuſpects, that this principle is perhaps a gas of a particular nature; its inviſibility, its volatility, the manner in which it is diffuſed in the atmoſphere, its expanſibility, and ſome experiments of Dr Ingenhouz upon the noxious gas of flowers, all go to ſupport this opinion. There only remains to make upon the ſubject experiments, which indeed require great care and accuracy, but which alſo promiſe brilliant and uſeful diſcoveries. Boyle has already ſaid much about the ſmells, their alterability, their reciprocal combination; and the ſubject has been continued with the greateſt ſucceſs by M. Lorry. This learned man has proſecuted the alterations reſulting from their mixture, from fermentation, the action of the fire, the air, and of different menſtrua. His intereſting memoir will appear in the next volnme of the Royal Society of Medicine. We cannot, without deviating from our plan, enter upon theſe details; but we ſuppoſe his firſt diviſion of the odours may be given. M. Lorry divides theſe bodies into five claſſes; the camphorated ſmells, the etherial, the poiſonous or narcotic, the acid, and alkaline. All the ſmells may be referred to theſe five primative claſſes. In giving a reaſon for this diviſion, this philoſopher confines himſelf to the effect the ſmells have upon the organs of ſmell and upon the nerves in general, without entering upon their chemical nature. But it is more than probable, as he thinks himſelf, that thoſe of every claſs approach to one another in their chemical nature, as we know they do in their action upon the animal œconomy.

The ſecond reflection with which we ſhall terminate the chemical hiſtory of the odorous principle is, that though the plants which have been called *inodorous*, are conſidered deſtitute of this principle, it is, nevertheleſs, now fully demonſtrated, that with the moſt gentle heat of a water-bath, a ſlightly odoriferous water may be extracted, but which plainly diſcovers the plant from which it was produced. I am aſſured, having often tried it along with M. Bucquet, that the plants deemed the moſt inodorous, as the mercury, plantain, &c. yield to the water-bath a water, which ſo ſenſibly emits their ſmell, that the one cannot be diſtinguiſhed from the other. It is true, that theſe inſipid ſpiritus rectors are very quickly decompoſed, and part with the ſmall odour which characteriſes them. They are altered, ferment, and alſo paſs to the acid or alkaline ſtate according to their quality.

There is an art founded upon the method of extracting the odorous part of vegetables, preſerving them, and fixing them in different ſubſtances, called *the art of perfuming*. The moſt part of its properties is entirely chemical.

Medicine makes great uſe of diſtilled waters. They have virtues different according to their nature: it is only thoſe diſtilled with a naked fire which are uſed, as is done in the proceſs for obtaining the eſſential oils. We may obſerve, that this manipulation is proper in the caſe of the aromatic eſſential waters, but that it is defective in regard to thoſe commonly called *inodorous*. It is our opinion, that diſtillation in a balneum mariæ is in-

indeſpenſably requiſite: this precaution not particularly attended to, they have a burnt or empyreumatic ſmell, without being charged with that of the plant. If the virtue of theſe waters reſides only in the ſpiritus rector, however weak it may be, it is certain that the manner in which they are prepared may deprive them of all the properties of which they might be poſſeſſed.

Of Reſinous Inflammable Juices.

THE name of reſins has been beſtowed upon dry inflammable matters, immiſcible with water, ſoluble in oils and in ſpirit of wine, running fluid from the trees which produce them; theſe matters are only oils which have become concrete by drying. The difference between balſams and reſins is not determined. Some give the name of *balſams* to fluid inflammable ſubſtances; ſome of them, however, are dry. Others alſo call the inflammable ſubſtances the moſt odorous. M. Bucquet has thrown great light upon this ſubject, by giving the name of *balſams* only to thoſe of theſe combuſtible ſubſtances which have a ſweet ſmell, which they can communicate to water, and which particularly contain the odorous acid ſalts, which may be obtained concrete by ſublimation, or by decoction in water.

§ 1. *Balſams.*

THE principal kinds of balſams may be reduced to the three following:

1. Benzoin. Two kinds of this are diſtinguiſhed; the amygdaloide, formed of white tears ſimilar to almonds, adhering by means of a brown juice. The common benzoin is brown and without tears; it emits a a very ſweet ſmell when it is heated or rubbed. The tree is unknown which furniſhes it. This balſam is imported to us from the kingdom of Siam and from the iſland of Sumatra. It yields but very little eſſential oil, on account of its ſolidity. It gives out to water an acid ſalt in needles, whoſe ſmell is ſtrong, and which cryſtalliſes

lizes by cooling. It is extracted alſo by a ſublimation. It is then called *flowers of benzoin.* This operation is done into tw glazed earthen veſſels, placed one above the other. The fire muſt be very gentle, otherwiſe the ſalt is brown. The paſteboard cone, which was formerly employed, allows the diſſipation of much of the flowers. The ſmell of this ſalt is ſtrong, exciting coughing: its taſte is acid: it reddens the ſyrup of violets, and effervеſces with the mild alkalis. Benzoin in a retort yields a very acid phlegm, a concrete brown ſalt of the ſame nature, a brown and thick oil; the charcoal remaining contains fixed alkali.

Benzoin diſſolves in ſpirit of wine; and its tincture, precipitated by water, gives the lac virginale. The ſalt of benzoin is employed as a very good expectorant and aperient in pituitous diſeaſes of the lungs, kidneys, &c. Its oil is reſolvent; it is uſed externally for paralytic members.

2. Balſam of Tolu, Peru, Carthagena. It is brought or contained in the cocoa nut, or in yellow tears, or in a fluid ſtate: it flows from the toluifera, placed by Linnæus in the decandria monogynia. It may be extracted from the ſhells by heating them in boiling water, which renders it fluid. It comes from South America, in a country ſituated between Carthagena and the Name of God, which the inhabitants call *Tolu*, and the Spaniards *Honduras*. When analiſed, it gives the ſame products as benzoin, and particularly a concrete acid ſalt: it is employed in diſeaſes of the lungs: a ſyrup is made with it.

3. Storax is in red and ſmooth, or brown and greaſy tears. It has a very ſtrong ſmell; it flows from the oriental liquidambar, a plant little known. M. Duhamel ſaw it flow from the aliboufier, a juice of a ſimilar ſmell. Newman analyſed ſtorax; he got very little eſſential oil, a concrete acid ſalt, and a fat oil. Its uſe is the ſame with that of benzoin; it is employed chiefly as a perfume.

LECTURE XLIX.

§ 2. RESINS.

RESINS differ from the balſams in their leſs agreeable odour, and particularly in giving no concrete acid. The principal kinds are the following.

1. The balſam of Mecca, Judea, Egypt, Grand Cairo. It is liquid, white, bitter, of a very ſtrong citron-ſmell. It flows from a tree called *amyris opobalſamum*, and claſſed by Linnæus in his Octandria Monogynia, and diſcovered in Arabia Felix by M. Forſkahl. This balſam yields eſſential oil to diſtillation: it is uſed as a vulnerary when incorporated with ſugar, yolks of eggs, &c.

2. The balſam of copahu, brown or yellow, which flows from a tree called *copaiba*, and called by Linnæus *copaifera*, and placed by this botaniſt in his Decandria Monogynia. The common kind, and likewiſe that of the balſam of Tolu, is a mixture of true balſam of copaiba and of turpentine, according to Cartheuſer. It is employed in ulcers of the lungs and of the bladder, like the former.

3. Turpentine of Chio flows from the turpentine tree, which produces the piſtachò nuts; it is of a white colour, or of a yellow inclining to blue. It yields a very fluid eſſential oil in a balneum mariæ; that which it gives with the naked fire is leſs fluid. The turpentine is afterwards more yellow: if it is diſtilled with water, it is white and ſilky. In this ſtate it is called *terebinthina cocta*. This is rare, and of almoſt no uſe.

4. Venice turpentine, or the reſin of the larch-tree, is what is commonly employed in medicine. It is uſed in its natural ſtate, or combined with the fixed alkali. This combination is called *Starkey's ſoap*. The Paris diſpenſatory preſcribes, for its preparation, to pour upon half a pound of nitre, fixed by tartar, and ſtill hot, four ounces of eſſential oil of turpentine; to agitate the mixture with an ivory ſpatula, and to cover the veſſel with paper. The oil is gradually added till

the whole forms into a white maſs. As this proceſs takes up ſeveral months, chemiſts have endeavoured to find out a more expeditious proceſs. M. Rouelle, by triturating the alkali drop by drop with the oil, and adding a little water near the end, prepared in three hours a very conſiderable quantity of ſoap. M. Baumé directs bruiſing upon a porphyry one part of alkali of tartar, dried with a heat nearly fit to fuſe it, and gradually to add two or three times its weight of eſſential oil of turpentine. When the mixture has acquired a ſoft conſiſtence, it is put into a glaſs cucurbit covered with paper, and ſet in a moiſt place. In five days the deliqueſcent alkali forms a layer of a liquor at the bottom of the veſſel, the ſoap is in the middle, and a portion of oil, which has acquired a red colour, ſwims a-top. M. Baumé thinks, that the alkali unites only to the portion of oil which is in the ſtate of reſin. M. le Gendre extends this idea, by propoſing to ſaturate in the cold the fixed alkali diſſolved with thickened oil of turpentine, or turpentine itſelf. This ſoap has a certain degree of ſolidity, which becomes gradually more conſiderable: it is formed of cryſtals, which have been conſidered as the combination of the acid of the oil with the alkali; but which, according to the Academicians of Dijon, is only the alkali ſaturated with aërial acid and cryſtalliſed. As this ſoap is very difficult to make, and very alterable, M. Macquer thinks, that when we wiſh to unite the properties of the eſſential oils with thoſe of ſoap, it is better to incorporate with the white medicinal ſoap a few drops of the eſſential oil, whoſe effects are known. The pure volatile alkali, triturated with turpentine, forms a ſolid ſoapy compound, which diſſolves very well in water, and renders it milky and frothy.

5. The reſin of the fir-tree is called *turpentine of Straſbourg*. It is collected, by piercing the veſicles of the bark of the fir-tree, which is very copious in the mountains of Switzerland.

6. Pitch is the juice of a kind of fir called *picea*. It is got by inciſions made in the bark. It melts with a gentle fire: it is ſqueezed through linen cloths, and received in caſks. This is the Bourgogne pitch, or white pitch: mixed with the *noir de fumée*, it gives the black pitch. When it is long kept melted with vinegar, it dries, becomes brown, and forms hard reſin. Its groſſeſt parts are burnt in a furnace, whoſe chimney ends in a ſmall apartment terminated by a cone of cloth. In this cone the ſmoke is condenſed, and forms a fine ſoot called *noir de fumée*.

7. The reſin of the pine which yields the pine-apple. This tree is cut towards the bottom; the reſin flows out into troughs. Theſe inciſions are continued upwards when the laſt yields no more reſin. When it runs fluid, it is called *galipot*; that which dries upon the tree in yellow maſſes is called *barras*. Theſe juices are liquefied in pots, and then they are thickened by the heat: they are filtered through mats of ſtraw, they are run into holes made in ſand, they are formed into loaves called *black pitch*. If ſome water is interpoſed, the matter becomes white, and forms reſin or pitch-reſin. The people of Provence diſtil in great the galipot; from it they extract an oil, which they call *oil of pitch*. It is from the roots and trunks of the pine that the tar is prepared; which is only the empyreumatic oil of this ſubſtance. The wood of the tree is put in a heap and covered with turf, and the fire applied. The oil which the heat diſengages not being able to paſs through the turf, is conveyed into a bucket by means of a gutter, and is collected and ſent to market by the name of *tar*.

8. Tacamahaca, reſina elemi, reſina animata, are little in uſe: the tree which yields the firſt is not known. Elemi comes from a kind of amyris: the oriental reſina animata or copal, whoſe origin is not known; the weſt animata or courbaril, which flows from the hy-

menæa,

menæa, a tree of South America, are employed in making of varniſhes.

9. Maſtich is in white tears like corn, of a weak ſmell: it flows from the turpentine and maſtich trees. It is uſed as an aſtringent and aromatic. It enters into the compoſition of dry varniſhes.

10. Sandarac is in white tears, more tranſparent than thoſe of maſtich. It is extracted from the juniper-tree between the wood and the bark: it is alſo called *varniſh*, becauſe it is greatly uſed in theſe preparations. It is uſed for putting upon ſcraped paper, to prevent its ſucking in the ink.

11. The reſin of guaiac, which is greeniſh, is employed in the gout. It flows from the guaiac-tree by inciſions.

12. The labdanum, or reſin from Candy, is blackiſh. The peaſants collect it with a rake, to which are fixed ſeveral ſkins of animals, which they rub upon the trees: they form it into kinds of cylinders, called *labdanum in tortis*. It is impure from a great deal of blackiſh ſand. It is uſed as an aſtringent.

13. Sanguis draconis, which is extracted from the dracæna draco, and from ſeveral other ſimilar trees. It is in flat or round leaves, or in ſmall ſpheres incloſed in red leaves, and knit together like a chapelet. It is uſed in medicine as an aſtringent.

§ 3. *Gum-reſins.*

The gum-reſins are juices mixed with reſin and extractive matter, which has been taken for a gummy ſubſtance. They flow by inciſion, and never naturally, from trees or plants, in the form of fluids like an emulſion, white, yellow, or red, which are dried more or leſs eaſily. Water, ſpirit of wine, wine, vinegar, all diſſolve only a part of the gum-reſins; they differ in the proportion of reſin and extract, and their analyſis yields very various reſults. The moſt important kinds to be known are the following.

1. Olibanum is in yellow tranſparent tears, of a very diſagreeable ſmell. What tree produces it is not known. Diſtillation furniſhes a little eſſential oil and an acid ſpirit, and leaves a very conſiderable remainder, owing to the extractive part which it contains. It is uſed as a reſolvent fumigation.

2. Galbanum is a thick juice, of a brown yellow and of a nauſeous ſmell. In Syria, Arabia, at the Cape of Good Hope, it flows from inciſions made in a plant of the ferulaceous kind, called *bubon galbanum.* Diſtilled in an open fire, it yields a blue eſſential oil, which after that becomes red, an acid ſpirit, a weighty empyreumatic oil. It is a good deobſtruent and antiſpaſmodic.

3. Scammony is of a blackiſh grey, of a ſtrong and nauſeous ſmell, of a bitter and very acrid taſte. We diſtinguiſh that of Aleppo, which is the pureſt; and that of Smyrna is weighty, black, and mixed with foreign ſubſtances. It is extracted from the convolvulus ſcammonia of Linnæus. The root of this plant, cut and expreſſed, furniſhes a white juice, which is dried and becomes black. Scammony contains a various quantity of extract and of reſin, according to the different ſpecimens; the cauſe of very different effects on different conſtitutions. It is employed as a purgative in the doſe of four grains to twelve: mixed with a ſoft extract, as that of the liquorice, it forms the ordinary diagrede. The juice of quinces is alſo uſed for this purpoſe. It is generally adminiſtered triturated with ſugar and ſweet almonds.

4. Gammboge is yellow, reddiſh, without ſmell, of a very acrid and corroſive taſte. It comes from Siam, China, Iſland of Ceylon: it is extracted from a large tree little known, called in the country *coddam pulli.* It contains a great deal of reſin, which renders it ſtrongly purgative in the doſe of four or ſix grains. It ought to be uſed internally with the greateſt attention.

5. Euphorbium is in yellow tears, rotten or carious,

without ſmell. It flows from inciſion of the euphorbium, which grows in Ethiopia, Libya, and Mauritania; it contains a very acrid reſin, and is ſtrongly purgative. It is little employed, unleſs externally in carious bones.

6. Aſafœtida is ſometimes in yellowiſh tears, and moſt commonly in loaves, formed of different agglutinated pieces. It is remarkable for its very fetid ſmell of garlic, and its bitter and nauſeous taſte. It is extracted from the root of a kind of ferula, which grows in Perſia, in the province of Choraſin, and which Linnæus has ſurnamed *aſafœtida*. The root of this plant is fleſhy and ſucculent; it furniſhes by expreſſion a white juice of a hideous ſmell, which the Indians eat as a ſeaſoner, and which they call *meat of the gods*. It is uſed internally as a powerful antiſpaſmodic, and externally as a diſcutient.

7. Aloes is a juice of a deep red and even brown colour, and conſiderably bitter.

Three kinds of it are diſtinguiſhed; ſuccotorine aloes, hepatic aloes, and caballine aloes; they differ only in purity. The firſt kind is the pureſt. M. de Juſſieu has ſeen the different aloes prepared at Morviedro in Spain with the leaves of the common aloes. Inciſions are made, the juice is allowed to flow, decanted from above the feculæ, and inſpiſſated in the ſun's heat. It is exported in leather ſacks, under the name of *ſuccotrine aloes*. The leaves are expreſſed, the juice purified by repoſe and dried: and this is the hepatic. Laſtly, the ſame leaves are more ſtrongly expreſſed, and the juice mixed with the leys of the two preceding; and this is called *caballine aloes*. The firſt aloes contains much leſs reſin than the two laſt, which are much more purgative. The firſt is uſed in medicine as a draſtic purge, and recommended as a provoker of the menſtrual and hemorrhoidal fluxes. It is recommended likewiſe as a very excellent hydragogue.

8. Myrrh is in reddiſh brilliant tears, of a ſtrong

very agreeable ſmell, a bitter taſte, preſenting in their fracture white lines of the form of claws. Some of theſe tears are entirely gummy and inſipid. Myrrh comes from Egypt, and particularly from Arabia, from the country of Troglodytes. The plant is not known from which it is obtained: it contains much more extract than reſin. It is uſed as a very good ſtomachic, antiſpaſmodic, and cordial. M. Cartheuſer recommends it to the learned, who have a delicate ſtomach, to chew it, and ſwallow it diluted in the ſaliva. It is uſed in ſurgery as a detergent, and to ſtop the progreſs of gangrene.

9. Gum ammoniac is ſometimes in white tears internally, and yellow tears externally, and frequently in maſſes reſembling thoſe of benzoin. Their white colour and fetid odour eaſily diſtinguiſh them. It is ſuſpected, that this gum-reſin, which is imported to us from Africa, is extracted from an umbelliferous plant, on account of the ſeeds that are in it. The phenomena of the ſolution of this ſubſtance by water and ſpirit of wine, and particularly its inflammability, aſſimilate it to the reſino-extractives of M. Rouelle.

Gum ammoniac is uſed in medicine as a very good deobſtruent in obſtinate obſtructions. It is exhibited in the doſe of a few grains in pills or emulſions: it enters alſo into the compoſition of ſeveral diſcutient and reſolvent plaſters.

Of the elaſtic Gum or Caoutc-houc.

Elastic gum is one of thoſe ſubſtances whoſe nature it is difficult to determine: Although its combuſtible property, part of which is extracted in America to give light, ſeems to aſſimilate it to the reſins, its elaſticity, ſoftneſs, and inſolubility in the menſtrua which generally diſſolve theſe ſubſtances, are ſo many characters which diſtinguiſh it from them.

The tree which yields it grows in ſeveral places of America. Long inciſions are made in its bark, ſo as to penetrate the wood: the white, more or leſs fluid, juice, is received into a veſſel, and then different utenſils are formed: it is applied in different layers upon moulds; it is dried in the ſun or at a fire. Different forms are marked upon it with a ſteel-rod: they are expoſed to ſmoke; and when they are very dry, the moulds are broken. Such is the formation of the elaſtic gum bottles brought into Europe.

The veſſels which are made with this ſubſtance are capable of containing water and other fluids without its being affected. When it is cut aſunder, and the ſides of the pieces applied together, they join and unite very firmly.

We are unacquainted with the action of the fire upon elaſtic gum; we know only that it ſoftens and kindles it.

It is inſoluble in water: we do not know what action the ſaline ſubſtances have upon it. M. Macquer, who tried to diſſolve it in different menſtrua, found that ſpirit of wine had no action upon it, as Meſſrs Condamine and Freſneau had already announced, Academy 1751; but that the oils diſſolved it by means of heat. However, as his intention was to convert it into a liquid ſtate, ſo as to be capable of being made uſe of, but to reſtore its properties by the evaporation of the ſolvent, M. Macquer was obliged to have recourſe to another menſtruum than the oils, becauſe theſe matters, however volatile, always altered it, and remained fixed, ſo as to deprive it of its elaſticity and force. Very highly-rectified ether, in which he eaſily effected its ſolution, entirely removed theſe objections by its evaporability, Acad. 1768; and though this liquor was very expenſive, he thought it right to ſhow this method of forming very uſeful utenſils; ſuch as flexible catheters, by applying ſucceſſive layers of this ſolution upon a wax mould, till they are of the thickneſs deſired. When the catheter is dry, it is plunged into boiling water, which liquefies the wax; and in this manner the wax is ſeparated from the mould. The ſoftneſs and elaſticity of this inſtrument render it very uſeful to ſuch perſons as are forced to carry about it continually.

Such was the knowledge acquired of elaſtic gum, when, in the month of April 1781, M. Berniard, who is celebrated for his accurate performances, inſerted in the Phyſical Journal a very good paper upon this ſingular ſubſtance. From his reſearches, this chemiſt concludes, that elaſtic gum is a kind of particular fat oil, coloured by a matter ſoluble in ſpirit of wine, and defiled by the ſoot of the ſmoke to which each layer is expoſed in the drying. Water does not at all alter it. Spirit of wine takes its colour from it by means of ebullition. The cauſtic fixed alkali has no action upon it. The oil of vitriol reduces it to a coaly ſtate, and is itſelf blackened, aſſuming the odour and volatility of ſulphureous acid. The nitrous acid acts upon this gum as upon leather, and turns it yellow. Spirit of nitre very readily deſtroys it. Marine acid alters it in no ſhape. Rectified vitriolic ether did not diſſolve it. This fact would appear ſingular, as the author ſays, to all thoſe who are acquainted with the accuracy and veracity of M. Macquer. Nitrous ether diſſolves it. This ſolution is yellow, and gives, by evaporation, a tranſparent friable ſubſtance, ſoluble in ſpirit of wine: in a word, a true reſin, formed, according to the author, by the action of the nitrous acid upon the elaſtic gum. Eſſential oil of lavender, and that of ſpikenard and turpentine, diſſolved it by means of a gentle heat: but they formed gluey fluids, which ſtuck to the hands more or leſs; and therefore could be of no uſe. A ſolution of elaſtic gum in oil of ſpikenard, mixed with ſpirit of wine, depoſited ſome white flocci, which were inſoluble in hot water, ſwam upon its ſurface, and by cooling became white and ſolid like wax; in a word, a true fat concrete oil.

Oil of camphor diſſolves elaſtic gum by mere maceration. In evaporating the ſolution, the camphor is volatiliſed, and there remained an amber-like matter, of a ſolid conſiſtence, and almoſt not gluey, which eaſily diſſolved in ſpirit of wine. The fat oils boiled upon elaſtic gum diſſolve it; wax likewiſe diſſolves it. This ſubſtance does not fuſe with the heat of boiling water; but when expoſed to the fire in a ſilver ſpoon, it is reduced into a black fat oil: it emits white vapours; it then remains fat and gluey although expoſed to the air for ſeveral months, and does not reſume the dryneſs and elaſticity, which are ſo uſeful for the purpoſes to which it is deſtined. Laſtly, M. Berniard finiſhed his experiments upon elaſtic gum with expoſing it to a naked fire. From an ounce of this matter he obtained very little phlegm; an oil, at firſt clear and light, then thick and coloured; and ſome volatile alkali; but does not deſcribe the quantity. A coal of twelve grains weight remained, ſimilar to that of the reſins. This chemiſt attributes the preſence of volatile alkali to the ſoot which colours the elaſtic gum.

We ſhall obſerve, upon this analyſis, that it does not very exactly demonſtrate the nature of elaſtic gum, as the acids in their action upon it do not ſhow the ſame upon the fat oils, which is much more rapid; as the cauſtic alkalis do not convert it into ſoap; as it fuſes only with a heat, much ſtronger than that which is neceſſary to melt the moſt ſolid fat oils; as no fat oil becomes elaſtic, and never dries like it.

Beſides, the author advances, in the fifth experiment, that this gum is compoſed of two diſtinct ſubſtances, which he has not demonſtrated; and he concludes with conſidering it as a product of human induſtry. From all theſe reflections, and many others which it might be poſſible to make upon this ſubject, otherwiſe very excellently handled by M. Berniard, it is our opinion much ſtill remains to be known, as he has ſaid himſelf, before its properties are fully underſtood, and before its nature is fully determined.

LECTURE L.

OF THE FECULÆ AND FARINÆ.

THE juices of vegetables, elaborated in their veſſels, thicken, and are gradually depoſited upon the ſurface of their fibres, for their nutrition and growth; or they accumulate in a more or leſs ſolid form in the different organs which compoſe them. After having ſpoken of the fluid parts of theſe organic ſubſtances, it is neceſſary to examine the ſubſtance which forms the texture of their different ſolids. It is alſo of great importance to know the nature of all the ſolid matters which compoſe the texture of vegetables: however, the knowledge acquired upon this ſubject ſeems to announce, that theſe organs, treated by the proceſſes which we are going to deſcribe, are reduced into a dry, powdery, inſipid, white or grey ſubſtance, or of different colours, inſoluble in cold water, and as it earthy, called *fecula.*

This ſubſtance is obtained, by reducing in a mortar a root, ſtem, leaf, or any ſeed, into a pulp. When theſe parts are ſucculent, they may be treated in this way without addition of water; but, in general, this fluid is uſed to facilitate the ſeparation of the fibres, and to carry off the divided powdery portion of their texture. Theſe parts thus reduced into a pulp are expreſſed: the juice or the water, which the force of the preſs ſqueezes out, is turbid, white, or coloured, and it gradually depoſites by repoſe a flocculent matter, in part fibrous, ſometimes powdery; which is the true fecula of the vegetable. Some parts of vegetables appear entirely formed of this matter; ſuch are the ſeeds of the graminous and leguminous plants, the tuberous roots, &c. Theſe parts furniſh in general the fineſt and moſt copious fecula. As to the tender ſtems and leaves, their more fibrous texture, when treated by the above-mentioned proceſs, never yields any but a coarſe depoſition, which is coloured, filamentous, and is called *coarſe fecula*. If, after having dried them well, they are powdered, and this powder is waſhed, the water carries off a much more fine fecula, perfectly reſembling that of the tuberous roots and graminous ſeeds. To the eyes of a chemiſt, then, theſe two genera of feculæ differ only in this, that the former comes from a leſs fibrous, leſs organiſed part, as if formed of cells, in which nature has depoſited the dry or farinaceous juice; whilſt the ſecond, of a fibrous texture, needs to be diſorganiſed and attenuated by art.

All the ſolids of vegetables may with rigour furniſh a kind of fecula; but as ſome of it is prepared in the arts, pharmacy, and for our food, it is that chiefly which we ſhall conſider. The fecula of briony, pomme de terre, caſſave, ſagou, ſalep, and ſtarch, are chiefly made uſe of.

1. In order to prepare the fecula of briony, the roots of this plant are taken freſh, the bark is taken off, they are filed down, and ſubmitted to the preſs. The juice which flows is white, and depoſites a very fine fecula. The juice is decanted off in twenty-four hours; the fecula is dried, as it contains a certain quantity of extract which the juice has left in it: it is very acrid, and purges violently: if it is waſhed before drying, it becomes finer and whiter, but it loſes at the ſame time its purgative virtue. This manner of preparing the fecula of briony furniſhes only a very ſmall quantity of it; but more of it may be got by applying more water to what remains in the preſs, by paſſing this water thro' a hair-ſieve, to ſeparate the coarſe fibrous parts, and allowing the fluid to ſettle. When this ſecond fecula is depoſited, the water is decanted, and the depoſition dried. It muſt be obſerved, that this fecula, obtained by waſhing the reſiduum of the preſs, is not purgative like the firſt; becauſe the water has carried away the extractive part poſſeſſing this virtue. M. Baumé has obſerved, that the fecula of briony, well waſhed, is ab-

abſolutely ſimilar to ſtarch, and that a powder for powdering the hair might be made from it, which would make great ſaving of wheat. In the ſame way, for the uſe of medicine, is prepared the fecula of the roots of colt's-foot and ſword-graſs.

2. The pommes de terre are one of the moſt uſeful alimentary ſubſtances, on account of their abundance and fertility. A very great quantity of very fine white fecula is eaſily procured from them, which furniſhes a light food by baking and boiling in water. This fecula is obtained by filing ſome of them above a ſieve, and pouring upon them a great quantity of water. This fluid carries along the moſt fine and divided portion of the fecula, and is allowed to depoſite by repoſe: the water is decanted, the fecula dried with a gentle heat; then it is in an extremely fine very white and light powder.

3. The Americans extract from the root of a very acrid plant, called *maneſe*, a very ſweet nouriſhing fecula, which they call *caſſave.* They take off the ſkin from the root; they file it, and put it into a conical ruſh baſket, of a very looſe texture, which they ſuſpend by means of a ſtick placed upon two wooden reſts. To the extremity of this baſket they fix a very weighty veſſel; which by its weight expreſſes the root, and receives the juice which flows out. This is a very acrid and dangerous poiſon. When the fecula is well preſſed, and deprived of all the juice which it contained, it is expoſed to ſmoke to dry it, and paſſed through a ſieve: it then forms the caſſave. This farina is ſpread upon a hot iron-plate in order to be baked; and it is turned, in order to give its two ſurfaces the reddiſh yellow colour which announces the baking: in this ſtate it is called loaves of *caſſave.* By heating it in a baſon, and agitating it from time to time, it aſſumes, upon drying, the form of grains, which are called *couac.* From the expreſſed juice a very fine ſweet fecula is pre-

cipitated, called *mouſſache*, which is employed in paſtry-work.

4. The ſagou is a dry fecula, reduced into grains by the action of the fire, which is imported from the Molucca Iſlands, Java, and the Philippines. It is extracted from a kind of palm, called *ladan*, in the Moluccas. The trunk of this tree contains a ſweet marrow, which the inhabitants extract after the trunk is felled. They bruiſe this marrow, and put it into a kind of cone or funnel, made of the bark of a tree, and laid upon a hair-ſieve; they waſh it with plenty of water, which carries through the holes of the ſieve the fineſt and whiteſt portion of the marrow; the fibrous portion remains upon the ſieve. The water which is charged with the moſt attenuated part is received into pots, and gradually depoſites the fecula which diſturbed its tranſparency. The clear water is decanted off, and the depoſition paſſed through perforated copper plates, which give it the form of ſmall grains called *ſagou;* the red colour at their ſurface is owing to the action of the fire, which ſerved to dry them. This kind of fecula diſſolves in hot water, and forms with milk or broth a ſort of light agreeable jelly, which is much recommended in phthiſical complaints.

5. Salep, ſalop, ſalab, &c. is the root of a kind of orchis, prepared in the Eaſt Indies. They pick out the fineſt bulbs of this plant, take off their bark, macerate them in cold water, and boil them; then they are tied together when they are well drained, and dried in the air. M. Jean Moult gave another proceſs for the preparation of ſalep, which may be made with all kinds of orchis. The roots are rubbed to dryneſs, or in water with a bruſh, to carry off the external pellicle, and then ſet to dry in an oven: they become very hard and very tranſparent. However, they may very eaſily be reduced into powder; and this powder, waſhed in hot water, forms a nouriſhing jelly, of whoſe virtue Geoffroy greatly boaſted in all the diſeaſes depending upon an

acrimony of the lymph, and particularly in the phthiſis and bilious dyſentery.

Starch, properly ſo called, is a fecula abſolutely like the preceding; but as the farina of wheat, of which it makes one of the conſtituent parts, is one of the moſt important ſubſtances, and worthy of chemical notice, we ſhall dwell a little longer upon this fecula than upon the reſt.

What is called *farina* is in general a dry, friable, inſipid ſubſtance; ſuſceptible of taſte and ſolubility by the action of fire, and formed of matters eaſily ſeparated from each other. This ſubſtance reſides in the graminous ſeeds; and particularly in wheat, rye, oats, rice, Indian corn, &c. The leguminous ſeeds ſeem alſo to contain a compound analogous to the farina: however, it is only the farina of wheat which enjoys the truly deſirable properties of this ſubſtance, becauſe it alone contains a juſt proportion of the different ſubſtances whoſe mixture gives riſe to theſe properties. Although the œconomical uſe of the farina of wheat be eſtabliſhed as the beſt nouriſhment from time immemorial, it is but a ſhort time ſince it was attempted to be chemically analiſed. M. Beccari, an Italian phyſician, and M. Keyſſell Meyer in Germany, are the firſt who endeavoured to ſeparate its different component parts. Meſſrs Rouelle, Spielman, Malouin, Parmentier, Poulletier de la Salle, and Macquer, have reſumed the taſk, and puſhed the matter much farther than they had done. From their different reſearches, and from our own experiments, we ſhall deliver what is to be ſaid upon the ſubject.

Water is the moſt proper agent, which is the leaſt capable of altering the different matters which it carries along with it, or which it ſeparates according to the laws of their ſolubility. This fluid is alſo the moſt ſucceſsfully employed in obtaining the different matters of which the farina of wheat is compoſed. For this purpoſe we form a paſte with ſome farina and water. We ſqueeze this paſte above a veſſel, and placed under another veſſel, which lets fall upon it a continued ſtream of water: this fluid, in its deſcent, carries along with it a very fine white powder, which renders it milky: the proceſs is thus continued, till the water which falls upon the paſte goes clear into the veſſel. Then the farina is found ſeparated into three ſubſtances; a greyiſh elaſtic matter, which remains in the hand, called the *glutinous part*, or *vegeto-animal part*, on account of its properties; a white powder, depoſited by the water, that is the fecula or ſtarch; and a fine matter in ſolution in the water, which appears to be a kind of mucous extract. Let us proceed to the properties of each of theſe three ſubſtances.

§ 1. *Of the glutinous part of the Wheat.*

The glutinous part is a tenacious, ductile, and elaſtic matter, of a whitiſh grey. When it is drawn out, it extends about twenty times the length it was before, and ſeems to be compoſed of fibres or filaments, adhering ſidewiſe, according to the direction in which it has been drawn. Upon letting it looſe, when extended, it reſumes, by its elaſticity, its former volume. By increaſing its dimenſions, it may be made to imitate ſufficiently well, by means of its poliſhed ſurface, the texture of animal-membranes. In this ſtate it firmly adheres to dry bodies, and forms a very tenacious glue, employed by ſome in the junction of broken porcelain, a long time before the chemical means of obtaining it was known.

Its ſmell is ſweet, as if mucous; its taſte is flat: expoſed to a fire which is capable of drying it quickly, it bubbles up prodigiouſly. It dries very well with a dry air or with a gentle heat; then it becomes ſemitranſparent, hard, and brittle, like common glue; it breaks like it, clean and with a crack.

If in this ſtate it is put upon a burning coal, or above the flame of a candle, it exhibits all the marks of an animal-ſubſtance; it leaps about, bubbles up, liquefies, is agitated, and burns like a feather or horn, emitting a ſtrong fetid ſmell. Diſtilled in a retort, it yields, as all animal-ſubſtances do, ſome alkaline ſpirit, concrete volatile alkali, and an empyreumatic oil: its coal is very difficult of incineration, and gives no fixed alkali.

Freſh gluten, expoſed to a hot moiſt air, changes and putrefies in the ſame way as the animal-parts: When it ſtill retains a little ſtarch, this laſt paſſes to the acid fermentation, retards and modifies the putrid fermentation, and converts it into a ſtate very like cheeſe. In like manner, M. Rouelle prepared with gluten a cheeſe, remarkably ſimilar in ſmell and taſte to thoſe of Gruyre and Holland, of a moderate fineneſs.

Water has no action upon the glutinous part: when it is boiled in this fluid, it becomes ſolid; it loſes its elaſticity and gluey quality; but it acquires neither taſte nor ſolubility in the ſaliva. We obſerve, however, that it is to the water which forms the paſte that the gluten owes its ſolidity and elaſticity; and in the farina this vegeto-animal portion, ſuſceptible of aſſuming a ſolid elaſtic form, was powdery, and not coheſive: but as ſome water was poured upon the farina, and it is mixed, theſe molecules, which ſhould poſſeſs the glutinous portion, abſorb this fluid, turn gluey by this means, and form at laſt the kind of elaſtic ſolid which is called *gluten*. Water, then, contributes greatly to the formation of this ſubſtance; and this ſubſtance ſhould be perhaps conſidered as a particular compound, which is ſaturated with water, and which can abſorb no more. It is true, that by depriving it of water by exſiccation, it totally loſes its elaſtic and gluey property.

The moſt part of the ſaline ſubſtances have a more or leſs remarkable action upon gluten. The fixed alkali by means of heat diſſolves it. This ſolution is troubled, and depoſits ſome gluten, not elaſtic, by the addition of acids.

The mineral acids diſſolve the gluten. The nitrous acid diſſolves it with great activity, emitting a great quantity of nitrous gas. This ſolution is yellow; that by the marine and vitriolic acids is of a violet brown. A kind of oily matter ſeparates from theſe ſolutions: the gluten is in a true ſtate of decompoſition.

M. Poulletier, to whom we owe all theſe nice experiments, diſcovered that ammoniacal ſalts might be extracted from theſe combinations diſſolved in water, ſpirit of wine, digeſted and evaporated in the open air. This diſcovery ſeems to prove, that the volatile alkali is ready formed in the gluten.

From what has been ſaid it appears, that it is entirely different from any ſubſtance we as yet know in vegetables; and it approaches in many characters to the fibrous part of the blood. It is this gluten which gives the farina of wheat the property of forming a very pliant paſte with water, and the facility with which it riſes. It ſeems not to exiſt, or at leaſt to exiſt in very ſmall quantity, in other farinas; ſuch as thoſe of rye, oats, French corn, rice, &c. all of which form ſolid paſtes, brittle, and not ductile, and which riſe only very little, or not at all, when expoſed only to the temperature which makes the paſte of the farina of corn to riſe. In this laſt alone, then, are to be really found all the neceſſary qualities for making good bread.

M. Rouelle junior ſays, that he found a glutinous ſubſtance, analagous to that of the farina of wheat, in the green feculæ of plants, which, in their analyſis, yield volatile alkali, and empyreumatic oil, as the glutinous part, of which we have juſt now ſpoke.

§ 2. *Of the Starch of Wheat.*

Starch, or the amylaceous matter, is the moſt copious part of the farina; it is it which precipitates from the water which carries it along with it, when we waſh the paſte with a view of obtaining the gluten pure. This ſubſtance is very fine, ſoft to the touch: it has no ſenſible taſte. It is of a grey white colour, and dirty when extracted in the manner deſcribed; but the ſtarch-makers render it extremely white, by leaving it among an acid water, which they name *aqua certa*. From the reſearches of M. Poulletier it appears, that the fermentation which is excited in this fluid whitens and purifies the ſtarch, by attenuating, and even deſtroying, the mucous extractive part which precipitates with it in the firſt water. Starch, chemically conſidered, is a mucilage of a particular nature. This mucilage, which has been conſidered falſely as an earth by ſome chemiſts, greatly differs from the glutinous part. It burns without emitting an empyreumatic odour like this laſt. Diſtilled in an open fire, it yields an acid phlegm of a brown colour, and a very thick empyreumatic oil towards the end of the proceſs. Its coal is very eaſily incinerated; in which ſtate it is found to contain ſome fixed alkali.

Starch is not ſoluble in cold water; but when it is made to boil in water, it forms a glue, or rather what is called *ſtarch*. This laſt, expoſed to the moiſt air, gradually loſes its conſiſtence, ferments, paſſes to the acid fermentation, and is covered with mouldineſs.

The action of the ſaline ſubſtances upon ſtarch has not yet been examined; but the account now given of ts properties may ſuffice to diſtinguiſh it from the glu- inous part. All the white feculæ above deſcribed are of the ſame nature with the amylaceous matter.

As ſtarch forms the greateſt part of the farina, there can be no doubt but that it is the principal alimentary ubſtance in bread. M. Beccari found, that the quan- ity of the glutinous part was from a fifth to a third, nd even more; and that this quantity varies according he qualities of the farina, which depend upon the kind of ear that furniſhed it, and according to the qualities which this laſt receives from the earth and from the atmoſphere.

§ 3. *Of the mucous extractive part of the Farina.*

UPON evaporating the clear water which ſerved to vaſh the paſte and depoſite the ſtarch, M. Poulletier ob-

obtained a matter of a brown yellow, viſcous, gluey, pitchy, whoſe taſte was very weakly ſaccharine. This ſubſtance, which this learned man called *mucoſo ſaccharine*, exhibited in its combuſtion and diſtillation all the phenomena of ſugar. It is it which excites the acid fermentation in the water which ſwims above the ſtarch; ſince, as M. Macquer has very well obſerved, this laſt is by no means ſoluble in cold water. The mucoſo-ſaccharine matter is only in very ſmall quantity in the farina of wheat: perhaps there are other farinæ in which it is more copious. It cannot be doubted, however ſmall the quantity of this ſubſtance be in the farina of wheat, but that it has a principal ſhare in the particular fermentation which takes place in the paſte, and which makes it, riſe. This motion, neceſſary for the formation of good bread, is ſtill little known in its nature. It ſeems that this can be only a beginning of the putrid fermentation in the gluten, the acid in the ſtarch, and perhaps the ſpirituous in the mucous ſaccharine matter; perhaps from theſe three commencing fermentations, which mutually oppoſe each other, the mixture little known ariſes, which is much lighter than the paſte, and which by baking forms bread. This is ſo far certain, that in bread, the three ſubſtances juſt now examined are found combined together, and ſo altered that they cannot be ſeparated. The action of heat is even ſufficient without the motion of fermentation to combine and alter theſe ſubſtances, in ſuch a way that the baked bread, without being raiſed, furniſhes no more glutinous part, according to M. Malouin.

From theſe details, we ſee how far the other farinæ, except thoſe of wheat, and ſtill more, how far the fruits or the leguminous and farinous ſeeds, ſuch as the beans, peaſe, cheſnuts, &c. are from poſſeſſing all the qualities neceſſary for the formation of good bread.

Of

Of the Colouring Parts of Vegetables.

VEGETABLES contain colouring parts in all their organs. Theſe parts greatly differ from one another; frequently a vegetable matter, which has no apparent colour, aſſumes a very remarkable one by certain menſtrua. The art of dyeing, all whoſe proceſſes are entirely chemical, is founded upon the ſolubility of the colouring parts in the different menſtrua, upon the manner of applying them to the ſubſtances to be dyed, and of rendering them fixed and tenacious in them. In examining the properties of each colouring matter, we ſhall have occaſion to ſpeak of the principles of this important art, of which Meſſrs Hellot, Macquer, le Pileur d'Apligny, Hequet d'Orval, Quatremere Dijonval, and l'Abbé Mazeas, have given ſo excellent deſcriptions.

It appears, that the colouring-matter of vegetables, properly ſo called, is not yet known. M. Rouelle ſuppoſed that the green part, ſo copious in the vegetable kingdom, was analogous to the gluten of the farina: but it is certain, that this matter preſents different chemical characters, according to the baſe to which it is united. It is then this baſe, rather than the colouring part itſelf, which we would wiſh to talk of, in ſaying, that ſuch or ſuch a colour is extractive, ſuch another reſinous. The real ſubſtance which colours each of the vegetable parts employed in the arts, is, no queſtion, a very ſubtile body, and perhaps as divided as the principle of ſmell. One might be led even to believe it is only particularly modified in the ſolid and liquid parts of vegetables.

It is requiſite to relate here, that the colour of vegetables depends entirely upon the contact of light. Might we ſuppoſe then, that it is a portion of this fluid which combines with the humours of vegetables? Phyſics and chemiſtry are ſtill very inadequate for the reſolution of this problem. However it be, as it is impoſſible to ſeparate entirely the colouring part of the vegetable baſe, to which it adheres, it is agreed to take both theſe ſubſtances together for the colouring part.

M. Macquer has, more diſtinctly than all the chemiſts, deſcribed the colouring part of vegetables, conſidered relatively to dyeing; and his theory upon the application and fixation of the colours in the ſubſtances to be dyed, is without contradiction the moſt ſatisfactory. As our intention is to unite this theory with the hiſtory of the colouring parts of vegetables, we ſhall conſider them relatively to theſe laſt properties.

1. A great number of vegetable parts, which are extractive or ſoapy, diſſolve very eaſily in water. Madder, dyer's-weed, logwood, Indian-wood, Braſil-wood, furniſh yellow or red colours of this kind. It is known that ſtuffs dyed with theſe colours ſhould loſe their dye in water: for that reaſon, to render theſe colours durable, a matter is uſed capable of fixing them by decompoſing them; as an acid ſalt, ſuch as red tartar, alum, and ſeveral others. Theſe ſalts are ſaid to to be eating. An uncombined acid would have the ſame effect, but it would alter the colouring part. The ſuperabundant portion of acid in the alum unites with the alkali of the colouring ſoapy extract, and precipitates, upon the body which is dyeing, the reſinous part which is inſoluble in water. However, this colouring portion, rendered inſoluble by alum, is of two kinds; the firſt is very ſolid, and reſiſts in the free air the ſoaps and all the proofs uſed in dyeing.

This firſt colour gets the name of *good* or *great dye*. The other is altered by the air, and particularly by the action of the proofs: it is called *falſe* or *ſmall dye*. It muſt be obſerved that it is wool which aſſumes the beſt colour; and then ſilk, cotton, hemp, and flax, are the ſubſtances which are dyed with more and more difficulty, and which retain leſs ſtrongly the colouring ſubſtances.

The authors who have treated of dyeing, have entertained different opinions upon the manner in which the colouring parts are applied to the ſubſtances expoſed to their contact. Several have imagined, that this took place only on account of the pores of the ſubſtances to be dyed, which are more or leſs great, and more or leſs numerous; and that wool aſſumed more colour than ſilk, only becauſe its pores were more open and more numerous. But M. Macquer thinks, that this application which is more or leſs eaſy, depends on the nature of the colouring part relative to the matter to be dyed; and that the colouring is a true painting, whoſe ſucceſs and adherence is owing to an affinity, and to an intimate union between the colour and the dyed ſubſtance. This celebrated chemiſt adopted this opinion from the great number of experiments which he made upon this art, which is much indebted to his diſcoveries.

2. There is another claſs of colouring ſubſtances, which ſeem to be compounds of ſoapy extracts and reſins. M. Macquer calls them *reſino-earthy*. When theſe ſubſtances are boiled in water, the reſinous matter which they contain diffuſes through the fluid by means of the heat and diſſolved ſoapy portion; but it is precipitated in proportion as the decoction or bath cools. When, then, any wool, or any other matter, is plunged into the decoction of a colouring mixture of this kind, the reſin precipitates by cooling, and is applied without any other preparation to theſe ſubſtances. As it is not ſoluble in water, it gives a colour of a good dye. The colouring parts of this nature are extracted from almoſt all aſtringent vegetables; ſuch as the ſhell of walnuts, the root of the walnut-tree, ſumac, the bark of the alder-tree, ſaunders, &c. Theſe colours are all yellow: the dyers call them *colours from roots*. They ſerve for the moſt part to form a very good coat upon which the other more brilliant colours are applied. It muſt alſo be remarked, that the colouring ingredients, which require no preparation neither for themſelves nor for the mat-

ters to be dyed, furniſh the kind of dyeing which is the moſt ſimple and moſt eaſily practiſed.

3. The colouring principle of ſeveral other ſubſtances reſides in a purely reſinous matter, inſoluble in water. Some of theſe ſubſtances are not even ſoluble in ſpirit of wine, but all are in the alkalis, which convert them into a kind of ſoapy ſtate, and render them ſoluble in water.

The principal colours of this nature which are employed in dyeing are the following:

a. Annotto, a kind of fecula, which is extracted by maceration from the ſeeds of the urucu purified in water. This fecula is depoſited during putrefaction: it is firſt red, but in time becomes of a brick colour. This paſte is waſhed in water with the alkali of aſhes of tartar, which we ſhall know very ſoon, and the ſubſtances to be dyed are plunged into this bath. A fine gold yellow or an orange colour is produced.

b. The flower of ſafflower or baſtard ſaffron, gives a very fine red colour by the ſame proceſs. This flower contains two diſtinct colouring parts; the one purely extractive and ſoluble in water; the other reſinous. To obtain this laſt, firſt the ſoluble part muſt be extracted by accurate waſhings in water; then it is mixed with tartar-aſhes or ſoda; the mixture is waſhed, and thus uſed for the tincture. But as the alkali alters and tarniſhes its colour, the dyed matter is ſteeped in water rendered acid by the juice of citrons: this acid ſeizes upon the alkali, and leaves the colouring matter, which it enlivens and converts to a red.

c, Archil is a paſte which is prepared from moſſes, which are macerated in urine and lime. This laſt diſengages the volatile alkali, which evolves the red colour. The archil diluted in water gives a tincture without any other preparation: the alkalis extract a violet colour; but it is a falſe teint: it is altered by the air, and the acids turn it yellow.

d, Indigo, whoſe blue is deep, violet, and as if coppery, is a fecula, which is prepared at St Domingo and the Antilles, by macerating in ſtone-troughs filled with water the ſtems of the indigo-tree oranillo. The water becomes blue; the ſtems are ſtruck ſtrongly, and the fecula precipitates. The indigo, precipitated from the water, is put into ſtraining-bags to drop through; it is then dried in ſmall wooden boxes, and broken into pieces when dry. It is conſidered as good when it ſwims upon water; and it burns entirely away upon a red iron. The colouring part is extracted by the alkalis, and it is applied to the ſtuffs, requiring no kind of preparation: the colour cannot be enlivened by the acids, which would alter the colour of the ſtuffs.

4. There are ſeveral colouring parts that are ſoluble in oils. Alkanet, or the red root of a kind of bugloſs, communicates its colour to oil. Spirit of wine alſo diſſolves ſome: the green feculæ are diſſolved in it as well as in oil.

It is eaſy to conceive, that no uſe of theſe colours can be made in dyeing, becauſe it is impoſſible to employ the ſubſtances which are neceſſary for extracting them.

Such is our principal knowledge of vegetable colours. Hence it reſults, that all the immediate principles of vegetables may be the baſe of theſe colouring parts; ſince ſome are found ſoapy, reſinous, and extractive. Some ſeem to be even of the nature of fat oils, ſince they are inſoluble both in water or in ſpirit of wine, whilſt they diſſolve very well in the alkalis. Laſtly, there are ſome analogous to the glutinous part, according to M. Rouelle. There is great room to believe, that experiments made upon this ſubject will bring to light ſeveral other properties in theſe matters, which are very abundant in vegetables; and they will contribute to the progreſs of dyeing, one of the arts to which chemiſtry may be of the greateſt ſervice.

LECTURE LI.

THE ANALYSIS OF PLANTS WITH THE NAKED FIRE.

AFTER having examined all the matters which may be extracted from vegetables by ſimple means, incapable of producing in them any change, and after having conſidered theſe matters as their immediate principle, it is neceſſary to take a view of the alterations which they may undergo from the fire.

Ancient chemiſts knew little more than this ſort of vegetable analyſis; and all their inveſtigations of the nature of theſe ſubſtances conſiſted in determining how much ſpirit, oil, and volatile ſalt, they gave to diſtillation. At preſent we have loſt all confidence in this means; we know only that almoſt all plants yield nearly the ſame products: and the diſtillation of a great number of theſe bodies performed by chemiſts, in other reſpects very valuable and intereſting, has ſerved only to deceive us in this analyſis. For how is it to be conceived, that the action of the fire, which is exerted upon alll the different principles contained in vegetables, ſuch as the extract, mucilage, oil, reſin, ſaline matter, and which decompoſes each of theſe principles in a particular manner, is able to throw any light upon the nature and quantity of theſe principles; particularly when we obſerve that the products of theſe different decompoſitions mutually combine and produce a new body, which did not exiſt in the vegetable before? The analyſis of vegetables in a retort, is then a complicated, falſe, and deceiving analyſis.

However, as in the chemical examination of any body, no means ſhould be neglected which art furniſhes in the diſcovery of its nature, recourſe may be had to this analyſis, with a view of obſerving its effects, well aware not to truſt too much to this kind of inveſtigation. It ſometimes even happens, that when, in proceſſes performed in order to know its chemical properties, we compare the effects of the aqueous, oily, and ſpirituous menſtrua upon it, with the alterations which they undergo on the part of the fire, theſe agree with the action of the ſolvents; and by the product of diſtillation, indicate the matter contained in the vegetable in more or leſs quantity, the nature of its ſalt, &c. But in order to perform this part of the analyſis with the naked fire, we muſt, 1. Fully know the action of the fire upon each immediate principle of vegetables, ſuch as the extract, the mucilage, the ſaline matter, the oily juices, fluid or dry. 2. We muſt compare the products of diſtillation of the vegetable entire, with thoſe which the immediate principles commonly yield when treated in the ſame way. 3. We muſt analyſe at the ſame time the vegetable by menſtrua, in order to diſcover the immediate principles, and to draw uſeful inductions upon the changes which the fire produces.

The proceſs neceſſary for diſtilling vegetables with the naked fire is very eaſily performed and ſimple. Into a retort of glaſs or earth, we put a given quantity of the dry vegetable: we take care to fill it only a half or two-thirds; we place it in a reverberatory furnace, and adjuſt a proper receiver. A receiver perforated with a ſmall hole was formerly recommended, with a view of giving vent to any air which might be diſengaged from the vegetable, and which endangers the rupture of the veſſels. Now we know, that the aëriform fluid which eſcapes from theſe bodies in diſtillation, is almoſt never any other air but aërial acid or inflammable gas. Therefore as theſe fluids are as much the product of the vegetable, decompoſed by the action of the fire, as the phlegm, the oils, and volatile ſalts, it is as important to collect them as theſe laſt: for this end we ſhould uſe a perforated receiver with a crooked ſyphon adapted to it, whoſe extremity is received in a veſſel full of water or rather of mercury. By this means the liquid products are collected in the recipient, and the aëriform fluids in the pneumato-chemical apparatus. When the ſubſtance which we are diſtilling is ſuſceptible of furniſhing a concrete ſalt, we adjuſt between the retort and the recipient another veſſel, upon whoſe ſides the ſalt ſublimes. In this kind of diſtillation the fire ſhould be gradually and cautiouſly raiſed to obtain the products in the order of their volatility, and to prevent our confounding them. We begin with a few coals placed under the retort, and gradually augment the heat till the retort is red and nothing more paſſes over. We leave all to cool, and then unlute the apparatus to examine the products obtained. Though the diſtillation of vegetables with the naked fire always yields us products upon which we cannot fully rely; theſe products, however, differ from one another materially enough to demand a careful diſtinction. What paſſes firſt is an aqueous liquor charged with ſome odorous and ſaline principles. This phlegm aſſumes from leſs to more colour and ſaline properties. To it a coloured oil ſucceeds, whoſe colour deepens as the diſtillation advances, and which at the ſame time acquires conſiſtence and weight. This oil is ſometimes light and fluid, at other times weighty and ſuſceptible of ſolidity. It conſtantly emits a ſtrong empyreumatic ſmell; at the ſame time a greater or leſs quantity of elaſtic fluids is diſengaged, which are either aërial acid or inflammable gas, and moſt commonly both mixed together. At this time alſo, the volatile ſalt ſublimes when the vegetable is of a nature to furniſh it. When all theſe matters are paſſed, the vegetable is reduced to a charry ſtate. Let us reſume each of theſe products, and ſee what their nature is, and to what ſubſtances they owe their formation.

The phlegm is owing to the water in the compoſition of the vegetable, and in part to the water of vegetation, particularly when the analyſed body is not entirely dry; it is more or leſs copious, in proportion as the vegetable has ſuffered a greater or leſs degree of exſiccation. This phlegm is coloured more or leſs red, from the ſmall quantity of oily matter which it carries over with it, and which is in a ſoapy ſtate, by means of the ſalt, which it generally holds in ſolution. The ſaline matter which is united with it is moſt commonly acid; on that account it generally reddens the ſyrup of violets, and effervefces with mild alkalis. This acid belongs to the mucilages and to the oils. Sometimes the phlegm is alkaline; as in the diſtillation of the nitrous cruciform plants, emulſive and farinous ſeeds. Frequently it is ammoniacal, becauſe the volatile alkali which ſucceeds the acid combines with it. This fact is confirmed by throwing a little fixed alkali or quicklime into the phlegm. When it is ammoniacal, a briſk ſmell of volatile alkali flies off. Although the acids of vegetables appear not to be all of the ſame nature, thoſe which are obtained in ſolution exhibit the ſame external marks; but they have not yet been ſufficiently examined to determine the nature of their properties exactly. The oils of vegetables obtained by diſtillation in a retort are all very odorous, high-coloured, and preſent quite the ſame properties. The parts of vegetables which contain a great quantity of theſe inflammable fluids, ſuch as the emulſive ſeeds, yield in their analyſis a great quantity of oil. The odorous plants furniſh one which retains a ſmall portion of their ſmell in the beginning of diſtillation, but which very ſoon aſſumes the characters of all theſe oils, that is, the colour, weight, and empyreumatic ſmell, which diſtinguiſh them. All theſe fluids are very inflammable; nitrous acid kindles them; they diſſolve in ſpirit of wine; and all reſemble the vegetable from which they are procured. By rectification they may all be rendered very fluid and light, colourleſs; in a word, in the ſtate of etherial or eſſential oils.

As to the volatile ſalt, which is only ſome mild volatile alkali, it is obtained from only a few vegetables; but we muſt not believe, as ſome chemiſts have advanced, that it is extracted only from the cruciform plants. In general, all the plants which contain a great quantity of nitre, fixed alkali, and oil, furniſh it more or leſs. It is very rare, however, that we obtain a certain quantity of it in a concrete ſtate; frequently it is diſſolved in the laſt portions of phlegm. This ſalt appears to be owing to the reciprocal action of the oil and of the fixed alkali; and on this account it for the moſt part does not paſs over till about the end of the diſtillation. It ſeems alſo, that that which is carried over by the phlegm in the analyſis of ſome plants, as the cruciform ones, the poppy, rue, is always the product of a new combination; ſince M. Rouelle junior has demonſtrated, that the firſt contain none of it in their natural ſtate.

The elaſtic fluids which are diſengaged during the diſtillation of vegetables, ſhould be reckoned alſo among the number of products. It appears that their nature depends upon that of the vegetable. A plant which contains a great deal of oily combuſtible fluids yields inflammable gas. Mucilages, again, yield aërial acid. We have, in the article Sugar, obſerved, that Meſſrs Bergman and Fontana extracted from its acid a great quantity of fixed air; and this laſt chemiſt believed that the vegetable acids were formed in great part of this elaſtic fluid. It is, then, not aſtoniſhing that the mucilages, in which M. Bergman found the ſame acid as in ſugar, yield in their analyſis aërial acid. Theſe aërial fluids paſs over only towards the end of the diſtillation, becauſe they are diſengaged only the inſtant that the vegetable is entirely decompoſed. Hales, who was unacquainted with their nature, obſerved, that the quantity of air diſengaged during the diſtillation of vegetables, was ſo much the greater the more ſolid the vegetables were; and conſequently he conſidered this element as the cement and the cauſe of the ſolidity in bodies. From theſe conſiderations we have juſt now delivered, it is evident how much we ſhould value this hypotheſis.

Of Vegetable Charcoal.

Charcoal is the black reſiduum which vegetables leave, after they have undergone a complete decompoſition of their volatile principles in cloſe veſſels. The property of yielding charcoal belongs only to the organic matters, which contain the combuſtible ſubſtance called *oil.* To the decompoſition of this laſt ſubſtance we aſcribe excluſively this formation of this ſubſtance.

The coal is in general black, brittle, ſonorous, and of little ſolidity. It retains the form of the vegetable, when this has been very conſiſtent, and when it contained but little fluid matter. If, on the contrary, we decompoſe a tender plant, and one which contains a great deal of juice, this, in its diſengagement, deſtroys the organic texture, and yields a friable coal, which does not exhibit the form of the decompoſed vegetable. The different vegetable matters furniſh coals more or leſs copious, according to the ſolidity or form of their texture. The woods yield much more than the herbs, the gums more than the reſins, and theſe laſt more than the fluid oils.

Charcoal is a ſubſtance enjoying very ſingular properties, which are in general little known. Although it is very important in chemiſtry, and preſents exceedingly particular phenomena, no chemiſt has yet undertaken to inveſtigate its nature. Stahl conſidered it as the principal focus of phlogiſton; and he is the chemiſt who has ſaid moſt upon the ſubject. Our knowledge of the properties of charcoal belongs almoſt entirely to the œconomical uſe which we are obliged to make of it; and the works of philoſophers upon it offer nothing complete.

Charcoal, as to its phyſical properties, differs according to the ſtate and nature of the vegetables employed for its formation. It is ſometimes hard, and then preſerves a part of the organiſation of the vegetable; at other times it is ſriable, and powdery. The pure oils yield one which is in very ſine, as if porphyriſed, grains: it is the black of ſmoke. From the ſame circumſtances alſo, it varies in weight. When it is well made, it has neither a ſenſible taſte nor ſmell. Its colour alſo follows the varieties of its other phyſical properties. In a word, it is of a more or leſs deep black, brilliant or unpoliſhed. But the moſt important examination of this product of fire concerns its chemical properties.

Charcoal, expoſed to the moſt violent fire in cloſe veſſels, is nowiſe altered. If it is heated in a pneumato-chemical apparatus, it yields ſome particular inflammable gas, of which we ſhall take more notice afterwards: it is in no degree altered in this experiment. If, on the contrary, it is heated with the contact of the air, then it burns, and is conſumed into cinders; but with particular phenomena, which it is requiſite carefully to diſtinguiſh from thoſe of the other combuſtible bodies. As ſoon as it kindles, it reddens and flames: it preſents a white flame, which is the larger the greater the maſs. It emits no kind of ſmoke: in the atmoſphere, of which it abſorbs a part of the pure air, it emits a vapour or deſtructive gas, which appears to be only aërial acid: laſtly, it gradually conſumes, and leaves a more or leſs white cinder, in part ſaline, and in part earthy. The different charcoals vary in their inflammability; and this is alſo the moſt uſeful diſtinction in the arts: ſome eaſily burn with flame, and are ſoon conſumed; others are kindled with difficulty, conſume only ſlowly, and are converted into cinders only after they have been red a very long time.

The combuſtion of charcoal has been explained very differently by different chemiſts. Stahl thought that it was owing to the diſengagement of phlogiſton. M. Macquer has adopted this opinion; adding, that the pure air is abſorbed at the ſame time that the phlogiſton is diſſipated. What is more ſtriking in this phenomenon is, the ſmall quantity of reſiduum which is left after combination: it ſeems that all this ſubſtance entirely evaporates; and this is probably what happens. M. Lavoiſier, no doubt, ſtruck with this important fact, thought he might advance, in a very good paper upon Combuſtion, Acad. 1777, that charcoal appropriates to itſelf the baſe of the air, and forms with it an acid *ſui generis*, which is fixed air or aërial acid; whilſt the portion of the matter of fire, which was the ſolvent of this baſe, is diſengaged, and preſented under the form of flame and of light, which is proper to it. According to this opinion, the aërial acid is a combination of charcoal with the baſe of air *. With regard to our own opinion of the matter, we adopt a theory which we think more ſimple: The inflammable gas, diſengaged in great quantity from the charcoal, combines with the dephlogiſticated air of the atmoſphere, and forms the aërial acid, which ſeems to be only a combination of theſe two bodies. Thus inflammable gas is to aërial acid what ſulphur is to the vitriolic acid, and nitrous gas to the nitrous acid. This agrees ſo much the better with the facts, as inflammable gas of charcoal precipitates lime-water when it is made to burn above this fluid, and appears really converted into aërial acid, by being combined with the pure air during its combuſtion. This fact, which I have often obſerved, and communicated to M. Bucquet, appeared to me very proper to favour the doctrine which I have preſented upon the nature of inflammable gas and of aërial acid; and I have had the pleaſure of ſeeing it confirmed by M. Lavoiſier, in his paper upon Pyrophyrus, Acad. 1777, of which I had no knowledge before its publication. However, let the cauſe be what it may, of the phenomena of this combuſtion, and the hypotheſis adopted in conſequence of this cauſe, the facts preſented are no leſs true; and theſe alone muſt command attention.

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* We muſt here refer to this chemiſt's theory, who conſiders pure or dephlogiſticated air as formed of a baſe united with the matter of fire, which gives it the aggregation of an elaſtic fluid.

Charcoal expoſed to the air attracts its humidity; probably becauſe it is very porous, and perhaps alſo on account of the ſalts which it contains, although theſe ſalts are not uncombined. Water alters it in no manner whatever; nor does it ſuffer any change from the earthy matters: but almoſt all the ſaline ſubſtances are ſuſceptible of acting upon it. M. Rouelle found, that the fixed alkali diſſolved a conſiderable quantity of it by fuſion.

The vitriolic acid decompoſes it in cloſe veſſels, according to M. Baumé, when a mixture of them are diſtilled to dryneſs.

The nitrous acid acts upon it in a much more rapid manner. Dr Prieſtley obſerved, that a great quantity of nitrous gas was diſengaged. M. Macquer obſerved the nitrous acid made a very ſenſible effervеſcence with this body by means of a certain degree of heat. M. Prouſt ſet on fire ſome charcoal by means of a nitrous acid, which weighed one ounce four gros and twenty-three grains in a bottle which contained an ounce of diſtilled water. The experiments of this chemiſt are ſo new and ſo important, that I think it proper to give his own words of them, as he has deſcribed them in his Obſervations upon the pyrophori of Alum, inſerted in the Journal of Medicine July 1778.

" A charcoal, extracted from the wild ſaffron, reduced to powder, and recently calcined, occaſioned a vivid detonation with nitrous acid, and the rapidity of the inflammation raiſed the powder with a very pretty effect. I calcined ſome very fine powder of ordinary charcoal, and the detonation ſucceeded very well.

" I introduced about a gros of powder of charcoal into a dry retort of glaſs. I then poured into it about a gros of nitrous acid: it had no ſooner got to the bottom of the retort, than the detonation took place with the greateſt rapidity: from the neck of the retort, whilſt in my hand, iſſued a flame more than four inches long, which brought with it ſome powder, and very deep coloured vapours of nitrous acid. Theſe vapours condenſed into a green liquor, not very fuming: it was the nitrous acid, weakened by the water, which entered into the compoſition of that which firſt detonated. I poured ſome freſh nitrous acid upon the charcoal which remained in the retort; I likewiſe kindled it when I had poured on all the quantity.

"I repeated this experiment with the black of calcined ſmoke: the ſame thing happened; only a very ſmall portion of cinder was found in the retort, ſometimes half vitrefied, and adhering to the bottom of the retort."

All charcoals are generally charged with a great quantity of humidity. It appeared to me, that calcined charcoal, kept from night to morning, was not more proper for theſe detonations; becauſe it was ſenſibly moiſtened in this ſpace of time. But what is moſt ſingular, is, that theſe experiments are capricious, and do not always ſucceed, although with the ſame charcoal, the ſame acid, and the ſame proportion. The beſt way of aſſuring ſucceſs ſeems to be, if we pour ſome acid upon the middle of the powder, it does not kindle; if, on the contrary, the acid is allowed to flow round the ſides of the crucible or capſule, and it reaches the bottom, the detonation goes from this point, the powder is raiſed, and kindled by the nitrous acid: when the nitrous acid comes to fail, the detonation ceaſes of itſelf, and the coal which ſurrounds it remains black.

We are not acquainted with the action of the other acids upon charcoal.

This body decompoſes by means of heat all vitriolic ſalts, and forms ſulphur with their acid.

It makes nitre detonate; which conſumes it by means of the pure air which it furniſhes by the action of the acid.

In chemiſtry and pharmacy, a preparation is made called *nitre fixed by charcoal.* Two parts of nitre and one of powdered charcoal are mixed together: the mixture is projected into a red hot crucible; a vivid detonation enſues. When all is over, a white maſs remains, which attracts humidity from the air, and is nothing elſe but the fixed alkali of the nitre and of the charcoal: by waſhing this ſubſtance, the water diſſolves the fixed alkali, and only an earthy matter remains.

Liver of ſulphur diſſolves charcoal with great facility, both by the dry and humid way: It is the ſubſtance which combines with it the moſt eaſily. For this diſcovery we are indebted to M. Rouelle.

The metals do not unite with charcoal, but their calces paſs to a metallic ſtate when they are heated more or leſs ſtrongly with this body. In the article of the Metals, we have ſeen how we ſhould judge of this phenomenon, and what are the different opinions of chemiſts about it.

The action of the vegetable ſubſtances upon charcoal has been little attended to. We only know, that when this ſubſtance is mixed with the fat oils, they may by this means be rendered inflammable by the nitrous acid; which confirms the elegant theory of M. Rouelle, of the inflammation of the oils by this acid.

All we have ſaid upon the known properties of charcoal, tends to prove, that it is compoſed of a combuſtible body, ſaline ſubſtances, earth, and a little water. Perhaps the combuſtible matter, which makes more than three-fourths of the charcoal, is inflammable gas. This is at leaſt what facts ſeem to ſhow. With regard to the reſt of its properties, a greater number of experiments muſt be made, before a deciſive opinion is given of its nature and properties.

Of the fixed Salts of Vegetables.

WHEN a vegetable charcoal has been burnt, there remains a grey blackiſh or white matter, according to the nature of the charcoal: this is called *cinder*. It is very compounded: when it is properly made, it contains only ſaline and earthy matters, frequently mixed with ſome iron: when the charcoal was not very combuſtible, it ſometimes ſtill contains a little inflammable matter. M. Lavoiſier, upon examining the cinders of the wood employed by the ſaltpetre-makers, found ſome extractive and reſino-extractive matters in them. The name of *fixed ſalts of plants* has been given to theſe ſaline ſubſtances, which are extracted by waſhing their cinders.

The incineration of vegetables is uſed to obtain three kinds of ſalts, of importance to be known:

1. Potaſhes, from which the vegetable fixed alkali is extracted, is prepared in the north by burning the wood, which grows there in great abundance.

This ſalt is very impure; it frequently contains combuſtible bodies which change its whiteneſs; many neutral ſalts, ſuch as ſelenite, vitriolated tartar, Glauber's ſalt, febrifugal ſalt, marine ſalt, and a little mineral alkali; ſome iron and earthy ſubſtances. In order to purify this ſalt, and to extract the vegetable alkali from it in its ſtate of purity, it is diſſolved in the ſmalleſt poſſible quantity of cold water. This fluid is charged with the alkali and ſome neutral ſalts; and it is ſeparated by filtration from the earth, coal, iron, and ſelenite, which potaſhes frequently contain. This ſolution is evaporated to a pellicle, and by repoſe and cooling allowed to form the cryſtals of the different neutral ſalts which it contains. When this ley, after ſeveral filtrations, cryſtalliſations, and evaporations, yields no more neutral ſalts, it is evaporated to dryneſs and calcined. This alkali is then vegetable alkali very pure: it always contains, however, ſome neutral ſalts, which may be ſtill ſeparated, by ſetting by a very charged ſolution, and ſeparating by filtration the depoſition which is formed. It may then be employed with certainty in the moſt delicate chemical experiments.

2. Soda, from whence the mineral alkali is extracted, is the reſiduum of combuſtion of the plants which grow at the ſide of the ſea. It is prepared at Alicant in Spain, at Languedoc, Cherbourg. It is made by burning different ſorts of plants. At Alicant they employ the kali; at Cherbourg, ſea-ware of all kinds, known by the name of *ſea-weed;* the former contains much more mineral alkali than the other, which gives almoſt none. Theſe plants are burnt very dry in a pit dug for the purpoſe. At Cherbourg, when the combuſtion is advanced, and the cinders are very hot, they are agitated and ſtruck ſtrongly with large ſticks. By the motion, this ſubſtance, which is hot enough to undergo a kind of ſemivitrification, is made into hard and ſolid pieces, which are ſent to market under the name of *ſalligot*, *la marie*, *alun catin*. The names which diſtinguiſh it beſt, and which announce its ſtate, are thoſe which it receives in the countries where it is manufactured, or from the plants which yield it. The ſoda of Alicant, alſo called ſoda of *barilla*, is the beſt for chemiſtry and all the arts, which require a great abundance of mineral alkali. The ſoda of Cherbourg or ſea-ware contains the leaſt alkali, and ought to be rejected in chemiſtry; though in glaſs-making it is employed with great ſucceſs. Soda, conſidered chemically, is a compound of mineral alkali, of vegetable alkali, though in ſmall quantity, of vitriolated tartar, of Glauber's ſalt, marine ſalt, charcoal; iron in the ſtate of Pruſſian blue, according to the obſervation of Henckel; and of earth, in part free, in part combined with the fixed alkali, as that of Cherbourg. In order to ſeparate theſe two ſubſtances, and to obtain the mineral alkali pure, it is waſhed with cold diſtilled water; the ley is filtrated to ſeparate the earth, the iron, and charry matters; then it is evaporated, as we have directed upon Potaſhes. This alkali is not ſo eaſily purified as that of potaſh, becauſe, as it cryſtalliſes more eaſily,

in its cryſtalliſation it mixes with the neutral ſalts which it contains.

Fixed ſalts are prepared in pharmacy under the name of *Takenius*. This chemiſt's proceſs conſiſts in putting into an iron veſſel the plant from which we want to extract the ſalt: the veſſel is heated till the bottom be red; the plant, which is continually ſtirred, exhales a great deal of fume: it kindles; then the veſſel is covered with a top, to allow the fume to diſſipate, but to ſuffocate the flame. By this means the plant is gradually conſumed; when it is reduced to a kind of black coal, it is waſhed with boiling water, the ley is evaporated to dryneſs, and a yellowiſh or brown ſalt is obtained. This ſalt is frequently alkaline: it contains a great deal of extractive matter which colours it, and which is found mixed with all the neutral ſalts which the plant contained. It is in a ſort of ſoapy ſtate; on which account it is employed in medicine with much ſucceſs: but we muſt not ſuppoſe that it has the ſame virtues with the plant from which it was extracted, as combuſtion neceſſarily alters its principles. Laſtly, it would be of importance to examine, by a chemical analyſis, the different fixed ſalts of plants prepared after the manner of Takenius, with a view of diſcovering the different ſaline and extractive ſubſtances which they contain, and with a view to determine their virtues, and the doſe in which each of them ſhould be given.

Of Vegetable Earths.

WHEN, by the ablution of the cinders of vegetables, all the ſaline matter has been carried away which they contain, no more remains but a powdery ſubſtance, more or leſs white or coloured, inſipid, inſoluble in water, which hitherto has been regarded as an earth. Some iron may be got by the application of a magnet. This metal was ready formed in the vegetable; and ſome naturaliſts have thought, that upon it the colours of vegetables depended. M. Baumé, who in his Memoirs upon the Clays mentioned the earthy reſiduum of vegetables, aſſerts, that it forms alum with the vitriolic acid and a kind of ſelenite, a little different from that which is produced from pure calcareous earth: the other acids yield with this reſiduum ſparry ſalts and a few martial ſalts. M. Bergman thinks from this, that the earth of vegetables is formed of clay, and of an earth approaching to the calcareous earths; although, according to him, it ſenſibly differs from it, ſince it does not form quicklime by the action of fire. He thinks that the clay is formed in theſe ſubſtances by the colliſions which the vitrefiable earth ſuffers, and by the action of the acids with which it combines; that the clay, once formed, paſſes to the ſtate of calcareous earth by the new elaborations which it undergoes in the vegetable veſſels.

We may be allowed to obſerve, that the diſcoveries made in Sweden upon the ſaline nature of animal bones, which are to theſe ſubſtances what the fibrous texture of vegetables ſeems to be, ſeem to announce, that the reſiduum of theſe laſt is nothing elſe than an earth. Perhaps an accurate analyſis, which as yet has not been made upon this ſubject, might inform us, that what has been taken for an earthy matter, is only a calcareous phoſphoric ſalt; we are allowed at leaſt to ſuſpect ſo far from the works of M. Margraaf, who extracted phoſphorus from muſtard and ſeveral other ſeeds.

LECTURE LII.

Of FERMENTATION *in general.*

AFTER having conſidered vegetables juſt as nature preſents them to us, we muſt be acquainted with the changes and alterations which they may undergo in different circumſtances. Theſe alterations, which entirely depend upon their nature, are owing always to a phenomenon which is called *fermentation.*

Fermentation is a ſpontaneous motion which is excited in a vegetable, and which totally changes its properties. This motion is proper to the fluids of the organic ſubſtances; and it is only the ſubſtances elaborated by the principle of vegetable or animal life which are ſuſceptible of it. Chemiſts have not ſufficiently inſiſted upon this important truth; the application of which to the phenomena of organiſed ſubſtances is ſingularly uſeful to medicine.

There are ſeveral circumſtances neceſſary to every kind of fermentation. Such as,

1. A certain degree of fluidity. In fact, dry ſubſtances ſuffer no ſuch alteration.

2. A more or leſs ſtrong heat. The degrees of heat vary in every ſpecies of fermentation; but cold impedes all.

3. The contact of air. On that account bodies are very well preſerved, and without alteration, in a vacuum.

Chemiſts have diſtinguiſhed, after Boerhaave, three kinds of fermentation: the ſpirituous, which furniſhes ardent ſpirits; the acetous fermentation, which yields the acid of vinegar; the putrid fermentation or putrefaction, which produces volatile alkali. It muſt be obſerved, that there are ſeveral fermentative motions which ſeem not to belong to theſe three kinds; ſuch are, perhaps, the bread-fermentation, that of inſipid mucilages, that which evolves the colouring parts. It has been ſuppoſed, that fermentation followed the orders juſt now mentioned; but there are ſome bodies which become acid without having previouſly undergone the ſpirituous fermentation, and there are others which putrefy without undergoing the two firſt.

Of the Spirituous Fermentation.

The ſpirituous fermentation is that which furniſhe ardent ſpirit. For the thorough underſtanding of this fermentation, we ſhall conſider, 1. The conditions neceſſary to produce it: 2. The phenomena which accompany it: 3. The different matters which are ſuſceptible of it: 4. The product which it yields.

§ 1. *Of the Conditions neceſſary to the Spirituous Fermentation.*

Experience has taught chemiſts, that all vegetable matters are not ſuſceptible of the ſpirituous fermentation; and that, in order that it may take place, it is neceſſary that ſeveral circumſtances be united: theſe are different objects, which we ſhall conſider as conditions neceſſary to the ſpirituous fermentation.

Theſe conditions are, 1. A ſaccharine mucilage. This matter alone is ſuſceptible of paſſing to the ſpirituous fermentation.

2. A fluidity, a little viſcous. A too fluid juice does not ferment more than a too thick one.

3. A heat from ten to fifteen degrees of Reaumur's thermometer.

4. A large maſs in which a rapid motion may be excited.

5. Acceſs of air, without which it cannot take place.

§ 2. *Of the Phenomena of the Spirituous Fermentation.*

When the five conditions juſt now mentioned are united, then the ſpirituous fermentation takes place; and it ſhows conſtant phenomena which characteriſe it. It has been obſerved,

1. It excites in the liquor a motion, which increaſes till the fermentation be well eſtabliſhed.

2. The volume of the mixture is much augmented; and this augmentation follows the progreſs of the motion.

3. The tranſparency of the liquor is troubled by opaque filaments, which are agitated and carried throughout the fluid.

4. A heat is produced, which increaſes to eighteen degrees, according to M. l'Abbé Rozier.

5. The ſolid parts mixed with the liquor are raiſed and ſwim a-top, on account of the air which is diſengaged.

6. A great quantity of aërial acid is diſengaged. This gas forms above the fermenting veſſel a layer, which is eaſily diſtinguiſhed from the air. In this air Dr Prieſtley and the Duc de Chaulnes made their excellent experiments. In it candles are extinguiſhed, animals die, lime diſſolved in water is precipitated, cauſtic alkalis are perfectly cryſtalliſed. It is this acid, contained above the fermenting veſſels, which expoſes the workmen who work about it to ſo great danger.

7. The diſengagement of this gas is accompanied with the formation of a great number of bubbles, which are owing only to the viſcous liquor which the acid is obliged to penetrate.

All theſe phenomena ceaſe, as the liquor, however mild and ſaccharine it was, becomes briſk, pungent, and capable of intoxicating.

§ 3. *Of the different Matters ſuſceptible of the Spirituous Fermentation.*

NECESSITY has induced men to prepare fermented liquors from a great variety of different ſubſtances; but experience has convinced us, that it can be formed by ſaccharine matters only. Among theſe laſt, thoſe of which we have made the moſt uſe, and which it is conſequently requiſite to examine, are the following.

1. The juice of grapes produces wine properly ſo called; the beſt of all the fermented liquors. In order to underſtand the art of cultivating the vine, the object of which is very important to the neceſſaries of life, it muſt be examined, 1. The nature of the ſoil where the vine grows. It is known, that a dry parched ſoil is in general very good for this plant, and that it does not agree with a fat ſtrong earth. 2. The treatment and culture of this vegetable: it is cut, and the branches are lopped, to ſtop the courſe of the ſap; care muſt be

taken that it be expoſed to the ſun, and particularly to the reflection of its rays from the earth, &c.; no manure is furniſhed to it, &c. 3. The hiſtory of the vegetation of the vine; of its expoſition; of its flouriſhing; of the formation of the grape; of its maturation. 4. The accidents to which it is expoſed; ſuch as cold, too much rain, moiſture. 5. The time of vintage, which ought to be dry and hot. This preliminary knowledge once acquired, the art of making wine ſhould be conſidered; which conſiſts in putting the grapes taken from the ſtalk into a veſſel; in expoſing them to a heat from fifteen to ſixteen degrees; in bruiſing, trampling, and agitating them: then the fermentation is excited, and all its phenomena begin. The juice of the grape, or the muſt, ought to be neither too fluid nor too thick; in the firſt caſe it is thickened by boiling, in the ſecond it is diluted with water. Upon this ſubject, we ſhould conſult the works of M. l'Abbé Rozier, and of M. Maupin. When the wine is made, it is taken out from below, and put into open barrels. It undergoes a ſecond inſenſible fermentation, which more intimately combines its principles: a fine lee precipitates, and a ſalt known by the name of *tartar*, which we ſhall afterwards examine. In order to preſerve it, linen rags impregnated with ſulphur are burnt in the veſſel in which it is contained.

It is alſo of importance to be acquainted with the different wines. France produces a great number of excellent wines. Thoſe of Bourgogne are the beſt for daily uſe. Their principles are perfectly combined, and there is none which prevails. The wines of Orleannois poſſeſs qualities very ſimilar to thoſe of Bourgogne, when time has diſſipated a little of their greenneſs, and has fixed the ardent ſpirit, which they contain to exceſs. The red wines of Champagne are very good and very delicate. The white not muſty wine of this country is much better than the muſty, whoſe pungent and ſouriſh taſte, as well as the property of lathering, depends upon the aërial acid which has been ſhut up when it has been put into the bottle before the end of the fermentation. The wines of Languedoc and of Guyenne are of a deep colour; great tonics and ſtomachics, particularly when they are old. The wines of Anjou are white, very ſpirituous, and very readily intoxicate.

With reſpect to the foreign wines, thoſe of Germany called *Rheniſh* and *Moſelle wines* are white, very ſpirituous: their taſte is cool and pungent; they very readily intoxicate. Some Italian wines, ſuch as thoſe of Orviette, Vicence, Lacryma Chriſti, are well fermented, and pretty much imitate the French wines. Thoſe of Spain are in general boiled, ſweet, little fermented, and very unhealthful. Thoſe, however, of Rota and Alicant muſt be excepted, which are juſtly accounted very uſeful ſtomachics and cordials.

2. The apples and pears yield cyder and perry: theſe kinds of wines are very good; and very good aquavitæ may be extracted from them, as M. d'Arcet has demonſtrated.

3. The cherries furniſh another good wine; from which may be extracted an aquavitæ, called by the Germans *kirchenwaſſer*.

4. Apricots, peaches, prunes, yield not ſo good wines.

5. Sugar diſſolved in water ferments eaſily: from this wine an aquavitæ may be procured called *taffia*, *rum*, *guildive*.

6. The graminous ſeeds, and particularly barley, furniſh a kind of wine called *beer*. The art of brewing conſiſts in the following proceſſes: The barley is macerated in water during thirty or forty hours, in order to ſoften it: when put up in a heap, it is left to ſhoot; it is dried at a furnace, terminated by a board, upon which the barley is laid; then it is ſearched, to ſeparate the ſhoots called *tournillons;* it is ground into a farina called *malt:* this farina is waſhed with hot water, which diſſolves the mucilage; this water is called the *firſt water:* ſome freſh water is poured upon the malt after its

being heated, and it forms the ſecond water: it is boiled, and ſet to ferment with hops and yeſt, in a veſſel called *guilloire:* when the fermentation is over, it is agitated: the beer is taken out in caſks: the ſecondary fermentation raiſes a ſcum called *yeſt*, which ſerves to excite the fermentation of the decoction of malt. The ſhooting evolves in the barley a ſaccharine matter, to which it owes the property of forming wine: the ſame might be made from other graminous ſeeds.

§ 4. *Of the Product of the Spirituous Fermentation.*

THE product of all theſe fermented ſubſtances is a particular liquor, more or leſs coloured, of an aromatic ſmell, a hot and pungent taſte; which animates the weakened fibres when they are taken in ſmall doſes, and which intoxicates when drunk immoderately: this is what is univerſally underſtood by wine.

1. Grape-wine, which we take for our example, is a compound of a great quantity of water, ardent ſpirit, eſſential ſalt called *tartar*, and of a colouring extracto-reſinous matter, to which the red wines owe their colour.

Before we ſhow the means of ſeparating theſe principles, the properties of wine, entire and not altered, and its uſes, muſt be known. Wine is capable to diſſolve many bodies, by means of the water, ardent ſpirit, and eſſential acid ſalt, of which it is formed. It unites with extracts, reſins, certain metals, &c. Upon theſe properties the preparation of the medicinal wines is founded; ſuch as the emetic wine, made by macerating two pounds of good white wine with four ounces of crocus metallorum: the liquor is filtrated; or it is employed, in a turbid ſtate, as a very good ſtimulant in apoplectic and paralytic caſes. 2. The chalybeate wine, made by digeſting an ounce of ſteel-filings with two pounds of white wine: it is an excellent tonic and aperient. 3. The vegetable wines, which are prepared either with red wine, in which aſtringent aromatic plants are digeſted; or with white wine, which is generally employed with the antiſcorbutic plants; or with Spaniſh wine: the vinum ſcilliticum is made with this wine, and alſo the laudanum liquidum of Sydenham. This laſt is made by digeſting ſeveral days two ounces of opium cut into ſlices, an ounce of ſaffron, a gros of canella, and cloves, bruiſed in a pound of Spaniſh wine. This medicine is a very good anodyne in the doſe of ſome drops, particularly when we obſerve that the opium does not weaken the patient, or does not ſtop ſome uſeful evacuation.

In order to decompoſe wine, and to ſeparate its different principles, the action of the fire is generally made uſe of. This liquor is diſtilled in an alembic of tinned copper, to which a recipient is adapted; as ſoon as the wine boils, a white, ſlightly opaque, and milky fluid is obtained, of a pungent and hot taſte, of a ſtrong and ſweet ſmell: the operation is carried on till the vapours which are raiſed ceaſe to kindle at a candle. This product is called *aquavitæ;* it is a compound of water, ardent ſpirit, and a ſmall quantity of oil, which deprives it of its tranſparency while it is diſtilling, and which colours it yellow afterwards. We ſhould not aſcribe the colour of the old aquavitæ in commerce to this kind of oil alone, which paſſes with it in diſtillation, but rather to the extractive matter of the wood, which it has diſſolved in the barrels in which it has been kept. Aquavitæ is the liquor from which the ardent ſpirit is got, as we ſhall ſee afterwards. After having furniſhed aquavitæ, the wine is of a deep colour, of an acid and auſtere taſte; it is troubled, and a great quantity of ſaline cryſtals is obſerved, which are juſt the tartar. This fluid, then, is quite decompoſed; and its former properties cannot be reſtored to it by combining the ſpirituous product with the reſiduum. This analyſis, therefore, is complicated. If the reſiduum of the wine, from which aquavitæ has been extracted, is evaporated, it aſſumes the form and conſiſtence of an extract. The colouring part may be ſeparated by ſpirit of wine, which does not touch the tartar. This kind of tincture is not precipitated by water. By evaporation to dryneſs, the reſiduum eaſily kindles, and is ſoluble in water: it is a true reſino-extractive ſubſtance, which the ardent ſpirit formed by fermentation has carried off from the covering of the grapes. From this analyſis it is evident, that wine is truly compoſed of water, ardent ſpirit, tartar, and colouring matter. We know the nature and properties of two of theſe ſubſtances, of the water and colouring extract; it now remains only to examine thoſe of ardent ſpirit and tatar.

Before we ſpeak of theſe two ſubſtances, we ſhould ſay a word of a ſubſtance which is precipitated from wine during fermentation, and called *lee.* It is a compound of ſtones and pieces of raiſins, of coarſe tartar and vitriolated tartar. Some aquavitæ is obtained by diſtilling it in an open fire. If it is treated in a retort, it gives ſome acid phlegm, oil, volatile alkali: its coal contains vitriolated tartar and fixed alkali. The incineration of the lee of wine, made in the open air, furniſhes a cauſtic vegetable alkali, mixed with ſome vitriolated tartar, which is known in the arts by the name of *lees of wine.* What we are going to ſay upon the properties of ſpirit of wine and of tartar, will complete what we have to ſay upon the lee.

LECTURE LIII. LIV.

AQUAVITÆ, which is obtained by diſtilling wine with a naked fire, is a compound of ardent ſpirit, water, and a ſmall portion of oily matter. In order to ſeparate theſe ſubſtances, and to obtain the ardent ſpirit pure, diſtillation is made uſe of. There are ſeveral proceſſes for diſtilling ſpirit of wine. M. Baumé directed to diſtil aquavitæ in a balneum mariæ a ſufficient number of times, in order to get off all the ſpirit. He recommends ſeparating the firſt fourth of the product of the firſt diſtillation, and likewiſe to ſet apart the firſt half of the product of the following diſtillations: all theſe firſt products are mixed together, and rectified with a gentle heat. The firſt half of the liquor which paſſes over in this rectification is the moſt pure and ſtrong ardent ſpirit, called *alkohol;* the remainder is a leſs ſtrong ſpirit, but ſtill very good for ordinary uſe. M. Rouelle preſcribed drawing over by diſtillation in a balneum mariæ the half of the aquavitæ employed; this firſt product is common ſpirit of wine: by rectifying it twice, and reducing it to about two-thirds, a ſtronger ſpirit is uſed, which is diſtilled a-freſh with water according to Kunckel's proceſs; water ſeparates the ſpirit from the oil which altered it. This ſpirit diſtilled with water is rectified, and then there is the greateſt certainty of having it perfectly pure. The reſiduum of the diſtilled aquavitæ is only a water charged with ſome colouring part, with a particular kind of oil floating a-top.

It is manifeſt, that this liquor, after the different proceſſes employed, may be of different degrees of ſtrength and purity. It is a long time ſince different methods of aſcertaining its purity were known. It was at firſt ſuppoſed that ſpirit of wine, which eaſily kindled, and which left no reſiduum, was very pure: but it is now known that the heat excited by its combuſtion is ſtrong enough to diſſipate all the phlegm which might be contained in it. A proof by gunpowder was propoſed: the ſpirit being kindled, when placed upon gunpowder in a veſſel, if the powder does not kindle it is conſidered bad; if, on the contrary, it takes fire, it is thought pretty good. But this proof is falſe and deceiving: for upon putting much ſpirit of wine upon powder, the water which it affords in its combuſtion moiſtens the powder which will not kindle, whilſt we might inflame it by making burn upon its ſurface a very ſmall quantity of phlegmatic ſpirit. This method, then, is not more certain than the former. Boerhaave has given a very good proceſs for diſcovering the purity of this fluid. It conſiſts of throwing into the ſpirit ſome very dry powder of fixed alkali: this ſalt unites with the ſuperabundant water of the ſpirit of wine, and it forms a more weighty and more coloured fluid than the ardent ſpirit, which does not mix with it but ſwims below. Laſtly, M. Baumé, conſidering that ſpirit of wine is ſo much lighter than water the purer it is, deviſed an aréometer, by whoſe means the degree of purity of this fluid and of all ſpirituous liquors may be exactly determined. This inſtrument being plunged into ſpirit of wine, ſinks the deeper the purer the ſpirit is. It is aſcertained by well-executed experiments, that the moſt pure and moſt highly rectified ſpirit of wine ſtands at thirty-eight degrees of his aréometer. In his Elements of Pharmacy, from page 463—479. may be ſeen the method of conſtructing this inſtrument, as well as the reſults which ſpirit of wine, mixed with different quantities of water gave; which may ſerve to ſhow comparatively the ſpirit of wine in the liquor which is examining.

Pure ardent ſpirit, obtained by the proceſs juſt now deſcribed, is a fluid of great tranſparency, mobility, and lightneſs, weighing ſix gros forty-eight grains in a bottle which holds an ounce of diſtilled water. Its ſmell is penetrating and agreeable; its taſte is ſharp and hot; it is extremely volatile. When it is heated even ſlightly in cloſe veſſels, it riſes and paſſes without alteration into the recipient; by this means it is concentrated and ſeparated from the little water which may adhere to it. On this account the firſt portions are the moſt ſweet, volatile, and pure. It is proper to obſerve, that when ſpirit of wine is diſtilled, a large quantity of air is always diſengaged: it might be ſuppoſed that it is the moſt pure ſpirituous part which is ſeparated from the water, and which is volatiliſed in the ſtate of gas. But Dr Prieſtley has demonſtrated, that ſpirit of wine cannot put on the ſtate of a permanent gas. When ardent ſpirit is diſtilled with the contact of air, it very ſoon kindles and preſents a ſlight flame, white in the middle and blue at the edges; it burns alſo without leaving any reſiduum, when it is properly dephlegmated. Several chemiſts have tried to aſcertain what burning ſpirit of wine yields. They have aſcertained that its flame is accompanied with no ſoot nor ſmoke; and that by receiving what is volatiliſed, only ſome pure water is obtained, inſipid, inodorous, and abſolutely in the ſtate of diſtilled water. It is therefore not known what becomes of the ſpirit in combuſtion. However, M. Berthollet has remarked, that when a mixture of this ſpirit and water is made to burn, the remaining fluid precipitates lime-water: this experiment ſeems to ſhow, that ardent ſpirit contains inflammable gas, which by its combuſtion or combination with the air forms aërial acid. Chemiſts, from the phenomena which this ſpirit preſents in inflammation, have adopted different opinions upon the ſubject. Stahl, Boerhaave, and ſeveral others, conſidered this fluid as a compound of a very attenuated oil, acid, and ſome water. According to this opinion, then, it is a kind of acid ſoap. Others, at the head of whom we may place Cartheuſer and Macquer, think that ſpirit of wine is formed of phlogiſton and water. Each of theſe opinions is ſupported by theory and experiment. We ſhall take notice which of them is moſt ſupported by facts.

Spirit of wine, expoſed to the air, evaporates at a temperature of ten degrees above the freezing point; and it leaves no kind of reſiduum, unleſs a little water, when it is not very much dephlegmated. This evaporation in the air is ſo much the more rapid the hotter the atmoſphere is; it produces a greater or leſs cold, according to its rapidity.

Spirit of wine unites with water in all proportions, and is perfectly ſoluble in it. This ſolution is attended with heat, and it forms kinds of aquavitæ ſo much the ſtronger as the ſpirit of wine is in greater quantity. The affinity of combination between theſe two fluids is ſo ſtrong, that water is able to ſeparate from ſpirit of wine ſeveral ſubſtances combined with it; and that, reciprocally, ſpirit of wine decompoſes the moſt part of the ſaline ſolutions, and precipitates the ſalts. From this laſt property, Boulduc propoſed uſing ſpirit of wine, in order to precipitate the ſalts contained in the mineral waters, and to obtain them without alteration.

Spirit of wine has no action upon the pure earths. It is not known if it might be altered by terra ponderoſa and magneſia. Lime ſeems ſuſceptible of occaſioning ſome change in it; ſince, when ſpirit of wine is diſtilled upon this earthy ſubſtance, this fluid acquires ſome ſmell: but this alteration has not been proſecuted.

Fixed alkali alters its nature, and really decompoſes ſpirit of wine, as is proved by the preparation known by the name of *acrid tincture of tartar.* In order to prepare this medicine, ſome ſalt of tartar is fuſed in a crucible; it is pulveriſed quite hot, and put into a matraſs; ſome very dephlegmated ſpirit of wine is poured on it to the height of three or four fingers-breadth above it; the matraſs is ſhut up with another ſmaller one; they are luted together, and the whole digeſted in a ſand-bath till the ſpirit of wine has acquired a reddiſh colour. More or leſs alkali remains at the bottom of the veſſel, and ſome cryſtals of neutral ſalts are obſerved, which M. Baron conſidered as vitriolated tartar previouſly contained in the alkali. Nevertheleſs, ſeveral chemiſts thought that this ſalt was partly formed by the union of the fixed alkali with the acid of the ſpirit of wine: but this point has not been properly examined. Upon diſtilling the acrid tincture of tartar, a ſpirit of wine is obtained of a ſweet odour little altered, and there remains in the retort a true ſoapy extract; which diſtilled in the naked fire yields ſome ſpirit of wine, volatile alkali, and a light empyreumatic oil. In this operation a little coal is formed, in which is found ſome fixed alkali. This experiment ſeems to demonſtrate, that ſpirit of wine contains an oil, with which the fixed alkali unites and forms a true ſoap, which is found diſſolved in the undecompoſed portion of ſpirit of wine. The lily of Paracelſus differs from the acrid tincture of tartar, only becauſe the fixed alkali employed in its preparation ſeems to have been made cauſtic by the metallic calces along with which it has been heated. The regulus of antimony, iron, tin, and copper, are fuſed together in the doſe of four ounces each; they are detonated with eighteen ounces of nitre and as much tartar; they are brought into fuſion; the mixture is pulveriſed, put into a matraſs, and ſome well dephlegmated ſpirit of wine is poured above it, to the height of three or four fingers breadth.

This mixture digeſted in a ſand-bath acquires a red colour deeper than the acrid tincture of tartar, and it preſents all the ſame phenomena: this laſt may be made entirely like the lily of Paracelſus by digeſting ſome ſpirit of wine with cauſtic fixed alkali, inſtead of uſing fixed ſalt of tartar, which the action of the fire does not entirely deprive of aërial acid, unleſs it be kept red for a long time.

The acrid tincture of tartar and the lily are very good tonics and powerful deobſtruents. They are employed in all the caſes where the ſtrength of patients is inſufficient to favour a criſis, as in the malignant fever, bad ſmall-pox, &c.

The action of the cauſtic volatile alkali upon ſpirit of wine has not yet been examined.

All acids exhibit with this fluid very remarkable phenomena. When very concentrated oil of vitriol is poured upon an equal part of rectified ſpirit of wine, a remarkable heat and hiſſing noiſe enſues: theſe two ſubſtances grow coloured, and at the ſame time a ſweet ſmell is diſengaged, reſembling that of citrons or rennets. If the retort in which the mixture generally is made, is placed in a ſand-bath heated, and if two large receivers are adapted, the firſt of which is plunged into a veſſel full of cold water, there comes over, 1. A ſpirit of wine of an agreeable ſmell. 2. A liquor called *ether*, of a very ſweet ſmell and extreme volatility, and whoſe preſence is announced by the ebullition of the liquor contained in the retort, and by the large ſtriæ which line the inſide of the veſſel. The receiver muſt be carefully cooled with wet cloths. 3. After the ether a ſulphureous ſpirit paſſes over, whoſe white colour and ſmell indicate that the apparatus ſhould be unluted, in order to ſeparate the ether. 4. A light yellowiſh oil is at the ſame time alſo volatiliſed, called *ſweet oil of wine.* The fire ought to be greatly moderated after the ether has paſſed, becauſe the matter contained in the retort is black, thick, and it bubbles up conſiderably. 5. When the ſweet oil is all diſtilled, ſome ſulphureous acid alſo paſſes over, and which becomes more and more thick; and at the end is no more than the oil of vitriol black and impure. 6. By continuing this operation with a gentle fire, the reſiduum is entirely dried, and has acquired the form and conſiſtence of a bitumen. An acid liquor is extracted from it, and a dry yellowiſh ſubſtance like ſulphur, by expoſing this bitumen to a very ſtrong fire. M. Baumé, who made many experiments upon vitriolic ether, examined the reſiduum with great care; he found ſome martial vitriol in it, ſome Pruſſian blue, a ſaline ſubſtance, and a particular earth, whoſe nature he did not determine. He ſays alſo, that the yellowiſh ſublimate which it furniſhes is not ſulphur, and that it remains white and powdery without inflaming upon coals. To theſe details we ſhall add, that the reſiduum of the ether may furniſh a new ſupply of ether, by adding to it a third of ſpirit dephlegmated by ſalt of tartar, and diſtilling this mixture. Theſe diſtillations might be ſeveral times repeated; and thus, from ſix pounds of oil of vitriol and ſpirit of wine, to which mixture five pounds of this laſt have been ſucceſſively added, more than two pounds of good ether may be extracted.

The operation juſt now deſcribed is one of the moſt ſingular in chemiſtry, from the phenomena which it preſents; and at the ſame time one of the moſt important, from the light which it is capable of throwing upon the compoſition of ſpirit of wine. There are two opinions upon the compoſition of ether, which it is neceſſary to make known. M. Macquer, who, as we have already ſaid, conſiders ſpirit of wine as a compound of water and phlogiſton, thinks that oil of vitriol carries off the water of this fluid, and brings it nearer and nearer to the characters of oils. Thus, according to this opinion, ſome ſpirit of wine paſſes over, at firſt little altered; then a fluid, which is in a middle ſtate between ſpirit of wine and oil, which is the ether; and laſtly, a true oil; becauſe the oil of vitriol acts with ſo much the more energy upon the principles of ſpirit of wine, as the heat employed to obtain the ether is more ſtrong. M Bucquet, ſtruck with a ſtrong objection which he had made to this theory, its being difficult to conceive how the oil of vitriol, charged at the beginning of its action upon ſpirit of wine with a certain quantity of water which it had carried off from this fluid, could, though phlegmatic, react ſufficiently upon another portion of the ſame ſpirit, ſo as to put it into an oily ſtate, propoſed another opinion upon the production of ether: He conſidered ſpirit of wine as a fluid compoſed of an oil, an acid, and water; he thought, that when the vitriolic acid was mixed with this ſpirit, a ſort of bituminous fluid reſulted, which by heat furniſhed the ſame principles as the bitumens; that is, a light, very odorous, and combuſtible oil; a kind of naphtha, which was the ether; and then an oil more coloured and leſs volatile than the former, which was the ſweet oil of wine. Indeed, we ſhall obſerve, from the properties of ether which we are going to examine, that this fluid has all the characters of a very ſubtile oil, ſuch as naphtha. The ether obtained by the proceſs juſt now deſcribed is not very pure; it is united with ſome ſpirit of wine and ſulphureous acid. It is rectified by diſtillation in a retort in a ſand-bath along with ſome cauſtic fixed alkali. This ſalt combines with the ſulphureous acid, and the ether paſſes over very pure with the moſt gentle heat. If the firſt half of this product is ſeparated, the pureſt and moſt highly rectified ether is obtained.

Ether is a much lighter fluid than ſpirit of wine, of a ſtrong ſmell, of a hot and pungent taſte. It is ſo volatile, that upon being poured out or agitated it is diſſipated in an inſtant. In its evaporation, it produces ſo great a cold, that it may congeal water, as M. Baumé has demonſtrated in his excellent experiments. It kindles very eaſily, as ſoon as it is heated in the open air or touched with a kindled body: the electric ſpark likewiſe kindles it. It emits a very luminous white flame; and it leaves a black mark upon the ſurface of a body expoſed to its flame. Ether diſſolves in ten parts of water, according to M. le Count de Lauraguais.

The phenomena which ether might preſent with all the ſaline ſubſtances, have not been examined; the action of ſome of the acids only is well known. Lime and the fixed alkalis do not appear ſuſceptible of changing it. The cauſtic volatile alkali combines with it in all proportions, and it forms a fluid, whoſe mixed ſmell might be very uſeful in aſphyxies and ſpaſmodic diſeaſes. Oil of vitriol becomes very hot with ether; and it may convert a great part of it into ſweet oil of wine by diſtillation. Fuming nitrous acid raiſes a conſiderable effervescence with it; and the ether in this experiment ſeems to become more conſiſtent, coloured, and oily. Ether has not been combined with the other ſaline matters, not even with the mineral inflammable ſubſtances. It is only aſcertained that it diſſolves the eſſential oils and reſins like ſpirit of wine; and phyſicians frequently employ ætherial tinctures. Ether is conſidered in medicine as a powerful tonic, and as a very good antiſpaſmodic. It is employed in hyſterical caſes, in ſpaſmodic colics. It readily oppoſes bad digeſtion which is cauſed by a weakneſs of the ſtomach. It ſhould be adminiſtred with prudence, becauſe it is known that its exceſſive uſe is dangerous: it is alſo uſed with great ſucceſs externally in pains of the head, burns, &c. Hoffman, who greatly ſtudied the combinations of ſpirit of wine with vitriolic acid, made uſe of a medicine compoſed of ſweet oil of wine diſſolved in ſpirit of wine, which he called *anodyne mineral liquor*. The Faculty of Medicine of Paris added ether to this liquor; and ordered in their diſpenſatory to prepare it by mixing two ounces of ſpirit of wine, which paſſes over before the ether, two ounces of ether, and twelve drops of ſweet oil of wine. This medicine is employed as the ether, but it has not nearly the ſame virtue.

Nitrous acid acts in a very rapid manner upon ſpirit of wine. This briſk action has hindered chemiſts from examining this combination ſo fully as that with oil of vitriol. M. Navier is the firſt who has given an eaſy proceſs for the making of nitrous ether. According to him, a very ſtrong bottle of Sêves is taken; twelve ounces of very pure and highly-rectified ſpirit of wine is poured into it and plunged into cold water, or, ſtill better, ice; eight ounces of ſpirit of nitre are added at ſeveral times, and the mixture agitated each time; the bottle ſhut up with a cork-ſtopper, which is ſtrengthened with leather, and well tied. The mixture is ſet in a by-place to prevent accidents from the fracture of the bottle, which ſometimes happens. In a few hours bubbles riſe from the bottom of the veſſel, and drops collect at the ſurface of the liquor, which gradually form a layer of true ether. This diſengagement goes on for four or ſix days. As ſoon as the motion is thought to have ceaſed, the cork is pierced with a ſharp probe to give vent to a certain quantity of air, which, without this precaution would burſt out upon unſtopping the bottle, and carry off the ether, which would be loſt. When the air is diſſipated, the bottle is uncorked, the liquor is poured into a funnel, whoſe neck is ſtopped with the ſinger, the reſiduum is ſeparated from the ether, which ſwims a-top, and is received into a ſeparate veſſel.

Mr Woulfe, a famous Engliſh chemiſt, has offered another proceſs for preparing nitrous ether. It conſiſts in employing numerous and very large veſſels, to allow plenty of room to the diſengaged air. A white glaſs veſſel, from eight to ten pints, is taken, terminated by a neck ſeven or eight feet long: it is placed upon a tripod ſufficiently high, in order that a refrigeratory may be placed below it: a tubulated head is adjuſted to this veſſel; to whoſe neck a glaſs tube of ſeven or eight feet long is adapted: this laſt is received by its lower extremity into a globe with two points, pierced below with a hole, to which a veſſel is joined: to the third tube of this globe are added the bottles which conſtitute Mr Woulfe's apparatus, which we have already ſeveral times deſcribed

When all theſe veſſels are well luted, a pound of well-rectified ſpirit of wine, and as much fuming ſpirit of nitre, is poured into the globe by the tube of the head; then the head is ſhut with a cryſtal ſtopper, which is tied down with leather. The mixture, as ſoon as made, becomes warm; vapours are diſengaged, which run rapidly through the neck of the globe. This being heated till the liquor boil, the nitrous acid paſſes over into the globe, which ſerves for the recipient. This proceſs, though very ingenious, has ſeveral inconveniences: the apparatus is long of being fixed, it is dear and very embarraſſing; beſides, it expoſes to danger, becauſe, in ſpite of the ſpace allowed to the vapours, they are ſo rapidly diſengaged, that the veſſels often burſt with conſiderable noiſe.

M. Bougues, anno 1773, publiſhed another method of making nitrous ether. He directs to mix, in a glaſs retort of eight pints, a pound of ſpirit of wine with a pound of weak nitrous acid, ſo as to ſtand no higher than 24 degrees of Baumé's areometer; to adapt to the retort a globe of twelve pints; to give paſſage to the air, by adjuſting two quills at the junction of the luting, and to diſtil with a very gentle heat, ſinking the retort but a very ſhort way into the ſand. In this way he got ſix ounces of a very pure nitrous ether. From what M. l'Abbé Rozier has ſaid, it appears that M. Mitouard employed, ſo late as the year 1770, a proceſs very ſimilar to M. Bougues.

This chemiſt put four ounces of fuming ſpirit of nitre, with twelve ounces of ſpirit of wine, into a retort for diſtiliation: the retort was ſunk but very ſlightly into the ſand. By this means, which appears the moſt ſimple of all, he obtained a nitrous ether, reſembling that of M. Navier. Laſtly, M. de la Planche, a Paris apothecary, has thought of two methods of preparing nitrous ether in a very commodious manner. The firſt conſiſts in putting ſome nitre into a tubulated free-ſtone retort, to which a large globe, or two joined together, are adapted, to pour through the tube, firſt oil of vitriol, and then ſpirit of wine. The vitriolic acid diſengages the nitrous, which reacts upon the ſpirit of wine, and almoſt inſtantly forms nitrous ether. As it might be ſuſpected that the ether thus prepared was in part vitriolic, he ſubſtituted to this firſt method another very ingenious proceſs. He adapts to a tubulated glaſs-retort, in which he has put ſix pounds of very dry nitre, a long neck and a globe, which communicates by means of a crooked tube with an empty bottle. This correſponds by means of a ſyphon with another bottle, which contains three pounds of the moſt perfect ſpirit of wine. The whole being well luted, and the retort placed upon warm cinders, three pounds of very pure oil of vitriol are put in upon the nitre through the tube of this laſt veſſel: the retort is ſhut with a cryſtal ſtopper, a boiling heat is applied, and it is kept up till the vapours ceaſe to paſs. In this experiment, the vitriolic acid diſengages the nitrous, which paſſes partly into the globe, and partly into the ſecond bottle. When the operation is finiſhed, the globe contains fuming ſpirit of nitre, the retort vitriolated tartar, and the ſecond bottle an etherial liquor. This is diſtilled in a retort with a ſingle globe, and only two thirds of the product are drawn over. This product is diſtilled with a fifth of fuming ſpirit of nitre, which is gradually poured upon it with a glaſs funnel with a long ſtem; only two thirds of it are taken. Laſtly, this ſecond product is rectified with ſome ſalt of tartar; only four ounces are drawn over with three-fourths of remainder. The four ounces are very pure nitrous ether; the three-fourths of remainder are a nitrous mineral anodyne liquor. The reſidua of the two rectifications are dulcified ſpirit of nitre.

The nitrous ether obtained by all theſe proceſſes is a yellowiſh fluid, as volatile as vitriolic ether: its ſmell bears ſome analogy to that of this laſt, although it is ſtronger and leſs agreeable; its taſte is hot and more diſagreeable. It contains a little ſuperabundant acid: it raiſes up the cork of the veſſel in which it is kept; becauſe a great quantity of air is continually diſengaged: burnt, it emits a more brilliant flame and a thicker ſmoke than vitriolic ether; it alſo leaves a more copious coal: laſtly, like the vitriolic ether, it takes gold from its ſolution, and charges itſelf with a certain quantity.

The reſiduum of nitrous ether is of a citron yellow colour; its odour is acid and aromatic; its taſte is pungent, and imitates that of diſtilled vinegar. If it is diſtilled, it yields, M. Baumé ſays, a clear liquor, of a more agreeable ſmell than that of nitrous ether, of an agreeable acid taſte: it reddens the ſyrup of violets, unites with water in all proportions, and effervеſces with mild alkali; then a yellow amber-like matter, friable, ſimilar to ſuccinum, which attracts humidity from the air, becomes pitchy, and diſſolves in water without rendering it mucilaginous, remains in the retort. M. Baumé calls this a gummy ſoapy ſubſtance. It yields upon diſtillation a few drops of an acidulous very clear liquor, of an oily conſiſtence, and of a ſlight empyreumatic odour. After diſtillation, there remains a ſpongy brilliant coal without taſte, and very fixed in the fire. M. Bucquet ſays, that if the liquor is evaporated which remains after the formation of nitrous ether, it acquires the conſiſtence of a mucilage, and in time ſaline cryſtals form very like hairy caterpillars, to which has been given the name of *cryſtals of Hierne*, from the chemiſt who firſt deſcribed them.

Nitrous ether may be employed in the ſame caſes as the vitriolic; but it muſt be given in a ſmaller doſe on account of its greater action *.

The

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* M. Baumé, who tried many experiments to determine the beſt mode of preparing nitrous ether, recommends the proportion of two parts of fuming nitrous acid to one part of ſpirit of wine. The uſe of a larger proportion of acid never fails to produce a moſt violent exploſion, which no precaution can prevent; and the employment of a larger proportion of ſpirit of wine would be unneceſſary, as ſome of it ſeems to remain undecompoſed in the reſiduum of the mixture from which the ether has been ſeparated. When we add the acid to the ſpirit, we always hear a crackling noiſe, which M. Baumé thinks muſt ariſe from the action of the acid upon the portion of the ſpirit with which it comes into contact, and which it dilates to a very great degree. But what I chiefly wiſh to mark here, is the occurrence of a phenomenon which happened during the extreme cold of laſt winter (1783), in preparing nitrous ether after M. Baumé's method.

The phial in which the acid was added to the ſpirit was placed in a freezing mixture of ſnow and ſalt, and both the ingredients were taken immediately from another cold expoſure.

After about half an ounce of acid was added, beſides the crackling noiſe which M. Baumé deſcribes, a number of ſpicular cryſtals were produced, which were collected, upon decanting the mixture, into another veſſel.

So curious and unexpected an appearance induced me to repeat the experiment under the ſame circumſtances; which I did as nearly as poſſible, though entirely without ſucceſs, as no cryſtals were produced in the mixture. After this failure, I cooled both the acid and ſpirit ſeparately, before mixture, down to 30 degrees below froſt in Fareinheit's ſcale, and alſo brought the phial in which they

The marine acid has no ſenſible action upon ſpirit of wine : this acid is only dulcified by ſimple mixture with this liquor, as the two others are, when mixed in ſmall quantity with ſpirit of wine. M. Baumé, in his Diſſertation upon Ether, ſays he obtained a little marine ether

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they were to be mixed to the ſame temperature. Upon mixing, under thoſe circumſtances, the experiment ſucceeded to my wiſh ; and exhibited a much larger number of ſpicular cryſtals than the firſt one. By ſome accident the veſſel was broke in which thoſe cryſtals were kept ; and I have not ſince had a convenient opportunity to repeat the experiment. There is indeed ſomething very inexplicable in this production of cryſtals, as the mixture of nitrous acid and good ſpirit of wine commonly produces a violent degree of heat, and cauſes the emiſſion of vapours which cannot be repreſſed.

M. Baumé found the production of the elaſtic fluid ſo extremely troubleſome and dangerous, that in order to avoid the inconvenience ariſing from the violent explosion, he contrived to fix an empty bladder to the mouth of the phial, to collect all the vapour which might be generated. This contrivance ſerved the purpoſe in preventing the danger of exploſions, though not without the loſs of ſome ether, which was always collected in a ſmaller quantity when this apparatus was employed. But there is a proceſs, very elegant in itſelf, and ſuperior to M. Baumé's, from the abſence of any troubleſome collection of inconſiderable vapour, which has been practiſed for ſome years paſt by Dr Black profeſſor of chemiſtry in the univerſity of Edinburgh. Dr Black takes two ounces of ſtrong nitrous acid, which he puts into a phial : he pours in, very ſlowly and gradually, a quantity of water nearly equal in bulk to the acid ; ſo that by trickling down the ſides of the phial, the water may float upon the ſurface of the acid without mixing : he next adds, in the ſame cautious and gradual manner, three ounces of highly-rectified ſpirit of wine ; ſo that the ſpirit may in its turn float upon the ſurface of the water in the ſame way that the water floats upon the ſurface of the acid. By this attentive mode of proceeding, Dr Black keeps the three fluids ſeparate by means of their different ſpecific gravities, and has a ſtratum of water interpoſed between the acid and ſpirit. After this he ſets the phial in a cool ſituation ; the acid gradually riſes up by attraction through the water, mixes with the ſpirit, and acts upon it ; and in proportion to this forms a quantity of nitrous ether, without any chance of producing elaſtic vapours. The ether formed by this proceſs is extremely pure, and very fragrant in the ſmell, and does not ſo neceſſarily require ſeparation from the acid by rectification as that by M. Baumé's proceſs.

ether by mixing the vapours of theſe two fluids. Ludolf and Pott employed butter of antimony. M. le Baron de Bornes preſcribed diſſolving flowers of zinc in marine acid, and diſtilling the ſalt concentrated by evaporation in cloſe veſſels with ſpirit of wine. By this proceſs we very eaſily get marine ether. But no perſon has proſecuted the ſubject with ſo great ardour and ſucceſs as M. le Marquis de Courtanvaux. According to the proceſs preſcribed by this chemiſt, a pint of ſpirit of wine, with two pounds and a half of fuming liquor of Libavius, a very ſtrong heat enſues, and a white ſuffocating vapour riſes, which diſappears upon agitating the mixture: an agreeable ſmell is diſengaged, and the liquor aſſumes a citron colour. The retort is put into a hot ſand-bath; two receivers are luted, the laſt of which is immerſed into cold water. A dephlegmated ſpirit of wine ſoon comes over, and then the ether: it is perceived by its ſweet ſmell and the ſtriæ which it forms in the inner ſurface of the retort. As ſoon as this ſmell changes and becomes ſtrong and ſuffocating, the receiver is changed, and the diſtillation continued: a clear acid liquor is obtained with ſome drops of a ſweet oil; a yellow matter ſucceeds of a butyraceous conſiſtence, a true butter of tin; and, laſtly, a brown heavy liquor, which emits very copious white vapours. There remains in the retort a powdery grey matter, which is a calx of tin. The product of ether is poured upon ſome oil of tartar in a retort; a briſk effervеſcence and copious precipitate enſues from the tin, which the acid that had paſſed over with the ether kept diſſolved. A little water is added, and the whole diſtilled with a gentle heat. About the half of this product is obtained as marine ether. All the liquors which paſs after this marine ether are very copious in tin: they attract humidity from the air, they unite with water without precipitating. It is not well known to what this ſo rapid action of the marine acid, contained in the fuming liquor upon on ſpirit of wine, ought to be aſcribed, when this acid pure has not the ſmalleſt effect: but it appears from M. Scheele's experiments, that the marine acid is in its dephlogiſticated ſtate, or, according to the new doctrine, overcharged with air; and hence its action in this ſtate.

M. de la Planche, an apothecary, propoſed preparing marine ether by pouring upon decrepitated marine ſalt in a tubulated retort ſome oil of vitriol and ſpirit of wine. The marine gas, diſengaged by the vitriolic acid, meets in the globe the ſpirit of wine in vapour, with which it combines. An acid ether reſults, which is rectified with fixed alkali by diſtillation. Marine ether is very tranſparent, very volatile: it has nearly the ſame ſmell as vitriolic ether has; it burns like it, and yields a ſmoke ſimilar to it. But it differs from it in two properties; the one is, its exhaling, in combuſtion, an odour as pungent and as active as that of ſulphureous acid; the other is, its having a ſtyptic taſte, reſembling that of alum. Theſe two phenomena intimate, that this ether is different, and perhaps leſs perfect than the other two: no doubt, upon a farther examination of its other properties, more ſingular differences will yet be found *.

After

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* To form pure marine ether was long conſidered as one of the moſt difficult problems in chemiſtry; and after all the perfection to which the proceſs has been brought by the labours of the Marquis de Courtanvaux, we cannot eaſily obtain marine ether, from the ſmall diſpoſition which the marine acid has to unite with ſpirit of wine. All chemiſts who have wrought upon the ſubject, know the amount of the difficulty from their own experience; and they have all been inclined to aſcribe the repugnance between the two fluids to the ſmall degree of attraction which ſubſiſts between this acid and phlogiſton. In the proceſs of making vitriolic ether, the vitriolic acid is known to act upon the principle of inflammability of the ſpirit of wine, ſo far at leaſt as to become highly phlogiſticated itſelf, and to be converted into the volatile ſulphureous acid. If, therefore, the muriatic acid could by any means be rendered capable of attracting phlogiſton, it might alſo acquire the power of decompoſing ſpirit of wine, and of forming marine ether. Struck with the

ſorce

After having given an account of the action of the three mineral acids upon ſpirit of wine, we muſt reſume the hiſtory of this fluid. The action of the other acids upon ſpirit of wine has been but very ſlightly examined. It is known that it eaſily unites with the acid of borax: this ſalt communicates to its flame a green colour; that the ſpirit of wine abſorbs more than its own volume of aërial acid. As to the neutral ſalts, M. Macquer has determined, that the vitriolic ſalts diſſolve but with difficulty in it, that the nitrous and marine ſalts unite much better, and that, in general, it diſſolves theſe ſubſtances ſo much the more eaſily that their acid is leſs adherent. Spirit of wine, boiled upon vitriolated tartar and Glauber's ſalt, diſſolved none of them. Aërated tartar and ſoda unite with it in ſmall quantity: the moſt part of the ammoniacal ſalts unite with it. The deliqueſcent earthy ſalts, ſuch as the calcareous nitrous and marine ſalts, and thoſe with baſe of magneſia, diſſolve very well in it. Some metallic ſalts alſo are very ſoluble in it; ſuch as martial vitriol in the ſtate of mother-water, nitre of copper, iron and copper in the marine acid, corroſive ſublimate: all the copper ſalts give a very beautiful green colour to its flame.

Spirit of wine does not diſſolve ſulphur in ſticks nor

force of this analogy, I endeavoured to bring the conjecture to the teſt of experiment, by mixing dephlogiſticated marine acid with highly-rectified ſpirit of wine. For this purpoſe, I put ſome marine acid into a retort along with ſome black mangameſe; placed the retort upon a ſand-heat, raiſed the fire, and directed the acid vapour into a receiver which contained ſpirit of wine. After a ſhort time, the marine acid vapour was perceived to make a ſenſible impreſſion upon the ardent ſpirit in the receiver; it formed an intimate union with the whole, and converted a portion into perfect ether, which was ſeparated from the reſt of the ſpirit by rectification. This etherial liquor, when purified, was found, upon examination, to be completely prepared, and in all its properties to correſpond with, if not to excel, the beſt marine ether made in a very tedious and complex manner. Its ſmell is highly fragrant, inclining to that of citrous, and its mobility nearly equal to that of either the vitriolic or nitrous. This proceſs is both eaſy and expeditious, and will afford a convenient method of obtaining marine ether to thoſe who wiſh to ſtudy the ſubject with greater accuracy.

in flowers; but it unites with it when theſe two bodies are in the ſtate of vapour, and come in contact, according to the diſcovery of M. le Count de Lauraguais. His proceſs conſiſts in putting flowers of ſulphur into a glaſs cucurbit, and in placing in the ſame veſſel, and upon the flowers of ſulphur, a glaſs-tumbler full of ſpirit of wine, heating the cucurbit in a ſand-bath, and adapting a head and recipient. The ſulphur is volatiliſed at the ſame time with the ſpirit of wine: theſe two ſubſtances combine; and the fluid which runs into the receiver is a little troubled, and emits a fetid odour. It contains about one grain of ſulphur in the gros of ſpirit of wine.

It has no action upon the metals nor their calces. It in part diſſolves ſome bitumens, ſuch as ſuccinum and ambergris; it does not touch thoſe that are black and as if charry: it is obſerved, that when it is diſtilled from above ſalt of tartar it unites better with theſe bitumens; and that this ſalt, mixed with theſe laſt, rendered them much more diſſoluble, undoubtedly by converting them into a ſoapy ſtate.

There are few vegetable ſubſtances upon which ſpirit of wine has not a more or leſs remarkable action: the extracts loſe their colouring part, and frequently all their ſubſtance, when they are of the nature of the extracto-reſinous or reſino-extractive bodies: the ſaccharine and ſoapy juices unite with it. M. Margraaf extracted by its means an eſſential ſaccharine ſalt from ſkirwort, parſnips, &c. But the ſubſtances with which it combines moſt eaſily are, the eſſential oils, the ſpiritus rector, camphor, balſams, and reſins. Charged with the ſpiritus rector, it is called a *ſpirituous diſtilled water*. To prepare theſe fluids, ſpirit of wine is diſtilled with the odorous plants in a balneum mariæ. The ſpirit attracts the principle of odour, and is volatiliſed along with it: it diſſolves alſo a part of their eſſential oil, which makes it whiten upon mixture with diſtilled water; but it is ſeparated from this foreign principle by rectifying it in a balneum mariæ with a very gentle heat; and care is taken to draw over only three-fourths of the ſpirit of wine employed, in order to have only the ſpiritus rector. Theſe ſpirituous diſtilled waters acquire an odour more agreeable as they become old; and it appears that the odorous principle combines more and more intimately with the ſpirit of wine. Spiritus rector has ſo great an affinity with ſpirit of wine, that this laſt is capable of carrying it off from the eſſential oils and water. In ſhort, by diſtilling ſpirit of wine from the eſſential oils and water, charged with the odour of a plant, the ſpirit ſeizes the odorous principle, and leaves the oil and water without odour. It is obſerved, that ſpirit of wine diſſolves better the heavy and thick eſſential oils, than thoſe which are more fluid and light. Water diſunites this compound: it precipitates the oil in the form of white and opaque globules; but the ſpiritus rector unites with the ſpirit of wine. Spirit of wine eaſily diſſolves camphor in the cold, but better by means of heat. This ſolution, very copious, as two gros in the ounce of ſpirit of wine, mixed with water which has been added gradually and by drops, yields a cryſtalline vegetation, obſerved by M. Romieu: it is a perpendicular filament, upon which needles are implanted which riſe from the filament under an angle of ſixty degrees. This experiment ſucceeds but rarely; and it requires much nicety in the quantity of water, cooling, &c.

The name of tinctures, elixirs, balſams, quinteſſence, has been given to the compounds of oily or reſinous juices, and ſpirit of wine, which is ſufficiently charged with theſe ſubſtances, to have a great colour, and to be copiouſly precipitated by water. They are, as the diſtilled waters, either ſimple, when they hold only one ſubſtance in ſolution; or compound, when they contain more. Theſe medicines are prepared in general by expoſing the juice in powder, or the plant dry, whoſe eſſential oil or reſin is to be diſſolved, to the action of the ſpirit of wine, which is aſſiſted by agitation and the gentle heat of the ſun or of a ſand-bath. When the reſins of ſeveral plants or any vegetable ſubſtances are to be extracted at a time, theſe ſubſtances muſt firſt be digeſted in the ſpirit which are moſt difficultly acted upon; and thoſe muſt be ſucceſſively expoſed to its action which are the moſt ſoluble: when this menſtruum is as fully charged as can be, it is filtrated. Sometimes a compound tincture is at once made, by mixing ſeveral ſimple tinctures: in this way the elixir proprietatis is prepared, by mixing the tincture of myrrh and that of ſaffron and aloes together. Reſins and balſams may be ſeparated from ſpirit of wine by pouring ſome water into the tinctures, or by diſtillation. But in theſe two caſes the ſpirit retains the odorous principle of theſe two ſubſtances. Water cannot decompoſe the tinctures formed of the reſino-extractive or extracto-reſinous ſubſtances; as thoſe of rhubarb, ſaffron, opium, gum ammoniac, &c. becauſe theſe two ſubſtances are equally ſoluble in theſe two menſtrua.

Spirit of wine and aquavitæ are of very extenſive and various uſes in life. The latter is drunk to ſupport oppreſſed ſpirits; but its exceſs is dangerous, as it dries the fibres, and produces tremors, palſies, obſtructions, dropſies. Pure ſpirit of wine, or united with camphor, is employed as an external remedy in ſtopping the progreſs of gangrenes.

Diſtilled ſpirituous waters are adminiſtered in medicine as tonic, cordial, antiſpaſmodic, ſtomachic, medicines. They are exhibited diluted with water or ſweetened with ſyrup.

Drinks are made with theſe waters and ſugar called *ratafias*. Theſe, well prepared and taken in ſmall quantity, may be very uſeful; but in general they agree with few perſons, and they may be hurtful to many. Exceſs in theſe kinds of liquors bodes the greateſt danger; and inſtead of ſtrengthening the body and ſtomach, as is very commonly believed, they produce for the moſt part an entirely oppoſite effect; thoſe which are the leaſt hurtful, when they are drunk rarely and moderately, ought to be prepared in the cold with one part of ſpirit of wine diſtilled upon the aromatic ſubſtance whoſe ſmell we wiſh to communicate to it, two parts of water, and one part of pure ſugar.

The tinctures have nearly the ſame virtues with the diſtilled ſpirituous waters; but their action is much ſtronger; for which reaſon they are employed in a much ſmaller doſe, or in the form of pills, or with wine, or alſo in aqueous liquors. The precipitate which they form in this liquor is likewiſe ſuſpended in the mixture; and beſides, the colouring part remains diſſolved in the ſpirit of wine.

Laſtly, ſpirit of wine, united with reſin-copal, the oil of ſpike or lavender, and that of turpentine, forms varniſhes called *dry varniſhes*; becauſe, by applying a layer of this compound to the bodies we want to varniſh, the ſpirit flies off readily, and leaves a tranſparent reſinous lamina. The eſſential oils which are mixed with them hinder them from drying too readily, and they prevent them from being brittle by the unctuoſity which they communicate.

LECTURE LV.

Of TARTAR.

TARTAR is an eſſential acid ſalt, united with a portion of vegetable alkali and oil, which is depoſited upon the ſides of the barrels during the inſenſible fermentation of the wine. It is not a product of the ſpirituous fermentation, as ſome chemiſts have ſuppoſed, ſince M. Rouelle junior found it ready formed in muſt and verjuice.

It is in the form of irregular plates, diſpoſed in layers, often filled with brilliant cryſtals, of an acid and vinous taſte. We diſtinguiſh white and red tartar; which do not differ but in the red's containing more extractive colouring part. Crude tartar, expoſed to the fire in cloſe veſſels, gives over an acid reddiſh phlegm, an oil at firſt light, then heavy, coloured, and empyreumatic; a little volatile alkali; and a great quantity of aërial acid, which Hales, Boerhaave, and ſeveral other chemiſts, miſtook for air. A coal remains which contains much fixed alkali, and which incinerates eaſily. By the combuſtion and incineration of the tartar, a very pure vegetable fixed alkali is extracted. Some tartar in powder is put into cornets of paper, which are then ſteeped in water; the cornets are arranged in a furnace between two beds of charcoal, which is kindled: when the fire is out, the cornets, which preſerve their form, are taken out; they are waſhed with cold diſtilled water, to ſee what they contain: the ley is filtrated, and evaporated to a pellicle; it is left to cool, to ſeparate from it the vitriolated tartar: the water is poured off from this ſalt, evaporated, and cryſtalliſed afreſh, till it yields no more vitriolated tartar: then it is evaporated to dryneſs; and by this means a vegetable fixed alkali is obtained, united with a portion of fixed air, and always containing a little vitriolated tartar.

Tartar diſſolves in water with difficulty, ſince an ounce of this fluid, at the temperature of ten degrees above ice, takes up only four grains. As it contains much oily and colouring matter, it is purified by ſolution and cryſtalliſation at Ancane and Calviſſon, in the neighbourhood of Montpelier. We owe the details of this purification to M. Figes. He has added them in a memoir, printed among thoſe of the Academy 1725. The tartar is made to boil in water; the ſolution is filtrated boiling: it turns turbid upon cooling, and depoſites irregular cryſtals, which form a paſte: this paſte is made to boil in copper veſſels with water, previouſly mixed with an argillaceous earth brought from the village of Merviel, two leagues from Montpelier: it throws off ſcums, which are carefully taken off, and then a ſaline pellicle is formed: the fire is lowered; the pellicle is broken, which mixes with the cryſtals which are precipitated from the ſolution: the cryſtals are waſhed with water to carry off the earth, which renders them impure; and they are ſent to market under the name of *cream* or *cryſtals of tartar;* which differ only in the cream being depoſited at the ſurface, while the cryſtals are depoſited at the bottom of the liquor. It ſeems that the white clay ſeems to deprive the tartar of its oily matter and extractive part.

At Venice, tartar is purified in a manner a little different, according to M. Deſmaretz: the ſalt in powder is diſſolved in boiling water; the impure matters which it contains are left to depoſite, and they are carefully taken away: the liquor yields cryſtals by repoſe and cooling. Theſe cryſtals are rediſſolved in water, which is heated ſlowly: when this new ſolution is boiling, bruiſed whites of eggs are thrown in, and aſhes paſſed through a ſieve: the aſhes are mixed fourteen or fifteen times: we take off the ſcum which the effervеſcence occaſions, and leave the liquor to ſettle. Very ſoon a pellicle, and very white ſaline cryſtals, are formed; the water is poured off, and the ſalt dried: this method alters the nature of tartar, and changes a part into vegetable ſalt. It is the cream of tartar, or tartar purified about Montpelier, whoſe properties we are going to examine.

Very pure cream of tartar is cryſtalliſed, but in a very irregular manner. It has a ſour and leſs vinous taſte than the crude tartar. When it is put upon a burning coal, it emits much ſmoke, which has a pungent empyreumatic ſmell: it becomes black and charry. Diſtilled in a glaſs retort in a pneumato-chemical apparatus, by conducting the fire gradually, a phlegm, at firſt ſlightly coloured and ſlightly acid, is obtained: then a ſtronger and deeper-coloured acid paſſes; an oil, which aſſumes gradually colour and conſiſtence, whoſe ſmell is empyreumatic; laſtly, ſome concrete volatile alkali, and a great quantity of aërial acid. A very copious coal remains in the retort, which, waſhed without incineration, yields abundance of fixed alkali. All theſe products may be rectified by diſtillation with a gentle fire. The phlegm paſſes over almoſt without colour; the oil becomes very white and very volatile in this rectification; the volatile alkali is in part combined with the acid, and is obtained in a ſeparate and pure ſtate only by diſtilling the laſt portions of phlegm with the addition of fixed alkali. As for the coal, the fixed vegetable alkali which it contains is not produced in the operation, as ſome chemiſts have imagined, who were not fully acquainted with the nature of cream of tartar; but it is ready prepared in this ſubſtance. It is to this fixed alkaline ſalt that the production of volatile alkali is owing, formed by the reaction of the former upon the oil: the quantity of this volatile ſalt may alſo be augmented by diſtilling the oil obtained from the cream of tartar from above the coal which is left in its analyſis in the retort.

Cream of tartar ſuffers no alteration from the air.

It diſſolves in twenty-eight times its weight of boiling water; and it cryſtalliſes by cooling, but in a very remarkable manner. A certain quantity of earth ſeparates from the ſolution of this ſalt, ariſing undoubtedly from that employed in this purification. This ſolution reddens the tincture of turnſol, and has an acid taſte.

It is uncertain what is the action of the quartzy, argillaceous, and ponderous earths upon cream of tartar. Meſſrs the Chemiſts of the Academy of Dijon have obſerved, that magneſia, formed with cream of tartar a ſoluble ſalt, which the fixed alkali decompoſed, and which evaporated in the free air, gave ſmall priſmatic cryſtals, diſpoſed like the rays of the ſun. This tartarous ſalt, expoſed to the fire, bubbles up, and is converted into a light coal.

Several chemiſts have very fully deſcribed the action of lime and chalk. When ſome chalk is thrown into a ſolution of cream of tartar, an effervеſcence is produced from the diſengagement of the aërial acid, and a very copious precipitate is formed: this precipitate is the combination of the tartarous acid and lime: the ſupernatant liquor contains a neutral ſalt fully formed in the cream of tartar, and compoſed of its acid united with the vegetable fixed alkali: this ſalt, as we ſhall ſee more fully afterwards, is known by the name of *ſoluble tartar.*

To M. Rouelle junior this excellent analyſis of cream of tartar is owing: it proves, 1. That this ſubſtance is compoſed of a ſuperabundant oily acid, and of a certain quantity of this acid, united with the vegetable fixed alkali in the ſtate of a neutral ſalt. 2. That the combination of the tartarous acid with lime forms a neutral ſalt having very little ſolubility. M. Prouſt diſcovered, that the calcareous tartarous ſalt, diſtilled in a retort, leaves a reſiduum which kindles in the air like pyrophyrus. M. Bergman, in his Diſſertation upon the Elective Attractions, gives a proceſs for ſeparating the tartarous acid from this ſalt. He preſcribes waſhing with diſtilled water the precipitate formed by chalk thrown into a ſolution of cream of tartar, putting this calx tartariſata into a phial, and pouring above it eight times its weight of vitriolic acid, formed of one part of oil of vitriol and eight parts of water. This mixture is left in digeſtion for twelve hours, and frequently agitated with a wooden ſpatula; the clear liquor above the depoſition is poured off; this is waſhed with water till it has no taſte, and this ley mixed with the firſt liquor. This is the tartarous acid. It is evident, that in this experiment the vitriolic acid has decompoſed the calx tartariſata, and formed ſelenite by diſengaging the tartarous acid which the water diſſolved. The acid thus obtained, contains almoſt always a little vitriolic acid; it is purified by adding a little calx tartariſata, whoſe acid is diſengaged by the vitriolic and left pure. M. Bergman adds, that the ſolution of this acid, evaporated to the conſiſtence of a clear ſyrup, yields laminated cryſtals, very ſeparate from one another; that theſe cryſtals blacken on the fire, yield to the retort an acidulated phlegm and a little oil; and that the coal which they leave is neither acid nor alkaline. From theſe details it appears, that the tartarous acid contains oil like all vegetable acids.

Cream of tartar unites very well with the different alkalis. Some powdered cream of tartar is thrown into a ſolution of fixed ſalt of tartar; a briſk efferveſcence ariſes, produced by the diſengagement of the aërial acid; cream of tartar is added to the point of ſaturation; the liquor is boiled half an hour and filtrated; it is evaporated and left to cool ſlowly; long ſquare cryſtals form, terminated by two-ſided figures. This ſalt is called *vegetable ſalt*, *ſoluble tartar*, *tartar tartariſata:* it has a bitter taſte; it becomes coaly when it is greatly heated; it is decompoſed in a retort, and yields an acid phlegm, oil, and a great quantity of fixed air; it attracts in a ſmall degree humidity from the air; it diſſolves in four parts of diſtilled water; it is decompoſed by the mineral acids, and likewiſe by moſt of the metallic ſolutions.

Cream of tartar, combined with the mineral alkali, forms the *ſal de Seignette*, ſo called from an apothecary of Rochelle, who was the firſt who made it known. It is prepared by putting twenty ounces of cream of tartar into four pounds of boiling water; very pure alkali of ſoda is added to the point of ſaturation, which is known when no more effervеſcence enſues upon addition of the alkali. This combination renders cream of tartar ſoluble. The liquor is evaporated to almoſt the conſiſtence of a ſyrup, and it yields by cooling very beautiful regular cryſtals, often of a conſiderable ſize. They are priſms with ſix, eight, or ten unequal ſides, truncated at right angles at their extremities. The priſms are for the moſt part cut into two in their length, and the larger ſide or baſe upon which they reſt is marked with two diagonal lines which croſs in the middle, and divide this baſe into four triangles. Sal de

Seignette, which was ſold at firſt as a ſecret, and diſcovered at the ſame time by Meſſrs Boulduc and Geoffroy 1731, has a bitter taſte; it is decompoſed in the fire as the vegetable ſalt; it effloreſces in the air, becauſe it contains much water of cryſtalliſation; it is almoſt as ſoluble as the vegetable ſalt, and decompoſable like it by the mineral acids and metallic ſolutions. The mother-water of this ſalt contains the portion of vegetable ſalt, which made part of the cream of tartar.

The volatile alkali forms with cream of tartar a tartarous ammoniacal ſalt, which cryſtalliſes very well by evaporation and cooling. M. Bucquet ſays, that its cryſtals are rhomboidal pyramids. M. Macquer obſerved ſome of them in large priſms with four, five, or ſix ſides; others ſwelled in the middle, and terminated by very acute points. And Meſſrs the Dijon Academicians, obtained ſome of it in parallelopipeds with two alternate two ſided figures. This ſalt has a cool taſte, and is decompoſed by the fire; it effloreſces in the air; it is more ſoluble in hot than in cold water, and cryſtalliſes by cooling; lime and the fixed alkalis diſengage its volatile alkali; it is decompoſed by the mineral acids and metallic ſolutions.

Meſſrs Pott and Margraaf heated cream of tartar with the mineral acids, and the latter extracted from it neutral ſalts reſembling thoſe which each of theſe acids forms with the vegetable fixed alkali; from whence he concluded, that this alkali is ready formed in the cream of tartar. M. Rouelle junior, who has made the moſt numerous and accurate experiments upon cream of tartar, obtained the ſame reſults. By putting a pound of very finely-powdered cream of tartar upon a pound of oil of vitriol, the mixture turns hot; their reciprocal action is favoured by the heat of a balneum mariæ and agitation with a glaſs-rod; this heat is continued for ten or twelve hours; the mixture becomes thick like milk, two or three ounces of boiling diſtilled water are poured upon it, which communicate fluidity; it is left in a balneum mariæ about two hours; then it is taken from the fire, and three pints of boiling diſtilled water are added. This ſolution is coloured and opaque, contains free vitriolic acid, a portion of cream of tartar undecompoſed, and vitriolated tartar. The exceſs of acid is ſaturated by chalk; the ſelenite precipitates with a little cream of tartar; the mixture is filtrated and evaporated; it yields a little cream of tartar and ſelenite till it be reduced to eighteen or twenty ounces; then it is decanted and evaporated a-new; it yields by repoſe cryſtals of true vitriolated tartar; all of which may be thus obtained by repeated evaporations and cryſtalliſations. This ſalt is mixed always with a little cream of tartar, and it conſumes upon a red iron; but by ablution with a proper quantity of diſtilled water it is diſſolved, and the cream of tartar remains at the bottom of the veſſel. Such is the proceſs deſcribed and repeated with ſucceſs by M. Berniard after M. Rouelle, *Journ. de Phyſique*, tom. 17. page 183, 184.

The nitrous and muriatic acids, treated in the ſame way with cream of tartar, yield nitre and febrifugal ſalt; which proves without any dubiety the preſence of fixed alkali in this ſubſtance.

Cream of tartar acquires ſolubility by the union of borax and ſedative ſalt, according to the experiments of M. de Laſſone. One part of this laſt ſalt may render ſoluble even four parts of cream of tartar. This mixed ſolution when evaporated yields a gummy, greeniſh, and ſtrongly acid ſalt.

Cream of tartar ſeems capable of uniting with moſt of the metallic ſubſtances, as demonſtrated by M. Monnet and the Dijon Academicians: But as all theſe combinations have been but ſlightly examined, we ſhall confine ourſelves to thoſe of antimony, mercury, lead, and iron, becauſe theſe compounds are moſt known, and moſt employed in medicine.

The combination of antimony with cream of tartar is called *ſtibiated* or *antimoniated tartar*. As it is one of the moſt important remedies which chemiſtry affords to medicine, its properties muſt be carefully examined. Since the time of Adrien de Mynſicht, who firſt made it known 1631, different preparations of it have been offered. The pharmacopœias and chemical works all differ, either in the antimonial ſubſtances which ſhould be employed, or in their quantity, and likewiſe in that of the water and cream of tartar; or, laſtly, in the method of making it. In M. Bergman's diſſertation upon this medicine, we have a very good ſketch of the different proceſſes offered expreſsly for its preparation. It has been ſucceſſively ordered to uſe the crocus metallorum, liver, glaſs, and flowers of antimony: ſome have directed to boil theſe with the cream of tartar and a greater or leſs quantity of water for ten or twelve hours: others require only an ebullition of half an hour: and, laſtly, ſome authors wiſh the filtrated ley evaporated to dryneſs; and others require it to be cryſtalliſed, and only the cryſtals to be employed in medicine. From theſe different methods, it muſt happen that the antimoniated tartar is not always the ſame, poſſeſſing different degrees of ſtrength; ſo that there cannot be any certainty in its effects. Thus M. Geoffroy, who examined ſeveral ſtibiated tartars of different degrees of ſtrength, found by analyſis, that the weakeſt contain in the ounce from thirty grains to a gros and eighteen grains of regulus; thoſe of a middle emetic quality a gros and a half; and the moſt powerful two gros ten grains. The glaſs of antimony has been preferred to the other antimoniated ſubſtances, becauſe it is one of the moſt ſoluble by cream of tartar: but this glaſs may be more or leſs calcined; and theſe different degrees of calcination ought to influence its emetic quality. However, by taking very tranſparent and porphyriſed glaſs of antimony, boiling it in water with an equal part of cream of tartar till this laſt be ſaturated, filtrating and evaporating this ſolution with a gentle heat, cryſtals of ſtibiated tartar are obtained by cooling and repoſe,

poſe, whoſe degrees of ſtrength ſeem to be very conſtant. The liquor is decanted and evaporated, and furniſhes, by different ſucceſſive evaporations, new cryſtals. The mother-water contains ſome ſulphur, vegetable alkali, and a certain quantity of liver of ſulphur. When we filtre the mixture of cream of tartar, glaſs of antimony and water, a kind of yellow or brown jelly remains upon the filtre, which M. Rouelle has deſcribed. This jelly diſtilled yields a very inflammable pyrophorus diſcovered by M. Prouſt.

M. Macquer has propoſed to ſubſtitute to the glaſs the powder of algaroth *, which by itſelf is a violent emetic;

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* This precipitate is commonly made by the addition of a large quantity of water, which attracts the acid, and occaſions the depoſition of the metallic part. The Edinburgh college, in adopting this proceſs, employ a ſolution of alkaline ſalt, which entirely frees the precipitate from any muriatic acid. It is evident, that the baſis of which tartar emetic is made in this proceſs, is always of a ſimilar nature, as the metals loſe phlogiſton before they are diſſolved in acids, and conſtantly fall equally calcined when the precipitation is not occaſioned by a body which can furniſh phlogiſton. Neither water nor alkali contains phlogiſton; ſo that by the uſe of either precipitant the powder of algaroth is exactly the ſame. In the common way of combining muriatic acid with antimony, this acid muſt firſt be united with mercury, as it does not directly attack the regulus; and the compoſition is completed by a decompoſition during diſtillation. But as this proceſs is extremely tedious and laborious, a ſet of experiments was lately made here, to accompliſh the end in an eaſier and more expeditious manner. It was obſerved, in the note upon manganeſe, that the marine acid undergoes great changes, and becomes vaſtly more active when diſtilled from the black calx of this metal. A trial was made how far the acid, in this ſtate, could diſſolve antimony directly, without the intervention of corroſive ſublimate. The marine acid and manganeſe were put into the retort, and the reguline antimony, as advantageouſly expoſed to the incondenſible ſteems of the acid as poſſible, into the receiver with a ſmall quantity of water. When the acid came over, it was found to attack the antimony, and to diſſolve it completely; ſo that when the proceſs was finiſhed, there was a perfect ſolution of antimony in muriatic acid. After the ſucceſs of this experiment, a trial was farther made of the action of this dephlogiſticated acid upon crude antimony. Here it was found to attack the antimony very

emetic; becauſe this powder, precipitated from the butter of antimony by water, is always of the ſame degree of ſtrength. M. Bergman adopted the opinion of M. Macquer; and ſince that time an emetic tartar is prepared in the laboratory of the Dijon academy, according to the method of this chemiſt and of M. de Laſſone. This medicine has been employed with the greateſt ſucceſs: it operates in the doſe of three grains without fatiguing the ſtomach or inteſtines. Stibiated tartar is cryſtalliſed in three-ſided pyramids: it is very tranſparent: it is decompoſed by the fire, and becomes charry;

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very powerfully, and at the ſame time the ſulphur. However, the power of dephlogiſticated marine acid vapours to decompoſe the ſulphur, does not impede the ſolution of the antimony which is firſt attacked by them. All this increaſed activity of the marine acid ariſes from the loſs of ſome phlogiſton, of which it had been robbed by the manganeſe. The ſolution formed in this way is equally perfect with any other, and furniſhes a precipitate of equal quality. This proceſs is vaſtly ſimpler than the common one, and at the ſame time leſs expenſive. Tartar emetic, prepared from this precipitate, is at preſent preferred above every other kind; at the ſame time it may be queſtioned, how far it is practicable to make tartar emetic of uniform ſtrength, by uſing glaſs of antimony, made according to M. Bergman's directions. In the ordinary proceſs, the degree of calcination which the metal ſuffers before fuſion is not determined with ſufficient accuracy. Therefore M. Bergman propoſes to ſubſtitute diaphoretic antimony, which is a perfect calx, with the addition of as much phlogiſton as is requiſite to vitrefy the mixture into a perfect glaſs. By this method a glaſs may be made which ſhall be almoſt conſtantly the ſame. Some ſulphur neceſſarily enters into the compoſition of the glaſs; without it no degree of calcination will produce any thing but an opaque white enamel. This is known by mixing regulus of antimony and diaphoretic antimony in various proportions, and expoſing the mixture to a melting heat, when we find the ſides of the crucible covered with a whitiſh glaſs, which does not bear the ſmalleſt reſemblance to true glaſs of antimony. Whether the powder of algaroth or glaſs of antimony be employed, we digeſt it in a ſufficient quantity of water along with the cream of tartar till the whole is diſſolved, and afterwards we evaporate the ſolution. There is ſome attention requiſite in collecting the cryſtals, as ſome of them ſhoot which contain no metal. After they are formed, they undergo a little change of colour from the diſſipation of ſome phlogiſton.

charry; it is efflореſcent, and becomes of a dirty and farinaceous white: it diſſolves in ſixty parts of côld water, and in much leſs of boiling water: it cryſtalliſes by cooling: the alkalis and lime decompoſe it; calcareous earth and pure water in a great doſe are capable of decompoſing it: whence it follows, that it ſhould be adminiſtered only in diſtilled water. Liver of ſulphur precipitates it in a red powder or kind of ſulphur auratum, and may be uſed as a teſt to diſcover this ſalt in any water. Iron ſeizes upon its tartarous acid, and ſeparates the calx of antimony: on this account emetic tartar ſhould not be made in iron veſſels. M. Durande, a celebrated phyſician of Dijon, propoſed making this medicine publicly, and by a uniform proceſs, as is uſually done to the theriaca. We are of opinion, that it would be very uſeful only in procuring a uniform tartar emetic, upon whoſe effects the phyſician might always depend.

The tartarous acid may be combined with mercury in two ways. One which M. Monnet mentioned, conſiſts in diſſolving in boiling water ſix parts of cream of tartar with one part of mercury, precipitated from the nitrous acid by fixed alkali. This liquor, filtrated and evaporated, yielded him cryſtals decompoſable by pure water. The ſecond means of uniting mercury with tartarous acid, is to pour the nitrous ſolution of this metal into one of vegetable ſalt, or ſalt de Seignette: a precipitate is obtained, formed by the union of the tartarous acid and mercury, and ordinary or rhomboidal nitre remains in ſolution.

Cream of tartar acts in a ſenſible manner upon the calces of lead. M. Rouelle junior ſays, that the ſaturnine ſalt which is formed in this operation does not remain in ſolution in the liquor; and that this laſt, when evaporated, furniſhes only ſome pure vegetable ſalt, which was ready formed in the cream of tartar. This is one of the proceſſes which was uſed to demonſtrate the preſence of fixed alkali in the tartar.

Copper and its calces are very eaſily attacked by the tartarous acid; a ſalt of a beautiful green reſults ſuſceptible of cryſtalliſation, but as yet not fully examined.

Iron is one of the metals upon which cream of tartar acts moſt efficaciouſly. A medicine is prepared, called *tartarus chalybeatus*, by boiling in twelve pounds of water four ounces of porphyriſed iron-filings and a pound of white tartar. When the tartar is diſſolved, the liquor is filtrated, it depoſites cryſtals: more are obtained by the evaporation of the mother-water. The tinctura martis tartariſata is prepared by making a paſte with ſix ounces of iron-filings, a pound of white tartar in powder, and ſufficiency of water: the mixture is left in repoſe for twenty-four hours; then it is diluted with twelve pounds of water, and the whole boiled for two hours, taking care to add water to replace the evaporated part: the liquor is decanted, filtrated, and inſpiſſated to the conſiſtence of ſyrup, and an ounce of ſpirit of wine added to it. M. Rouelle ſays, that the vegetable fixed alkali is free in this tincture; and that in treating it by the acids neutral ſalts are obtained, which ſhow the preſence of this alkali. There are ſtill two medicines formed by the combination of the tartarous acid and iron; the one is the martial ſoluble tartar, which is a mixture of one pound of tartariſed tincture of mars and four ounces of vegetable ſalt evaporated to dryneſs; the other is known by the name of *martial balls*. They are made by putting one part of ſteel-filings and two parts of powdered white tartar into a glaſs veſſel, with a certain quantity of aquavitæ. When this liquor is evaporated, the maſs is pulveriſed, and ſome more aquavitæ added, which is again allowed to evaporate like the firſt. This proceſs is repeated till the mixture be thick and tenacious; then it is formed into balls.

Crude tartar is very uſeful in dyeing; it is uſed alſo by the hatters.

The different preparations of cream of tartar juſt now enumerated, are employed moſtly in medicine. Pure cream of tartar is conſidered as a refrigerant and antiſeptic: in the doſe of half an ounce or an ounce, it is a gentle, not nauſeating, laxative. The vegetable ſalt and that of Seignette are in frequent uſe, as aſſiſtant purges, in the doſe of a few gros. Stibiated tarter is one of the moſt uſeful and powerful remedies for which medicine is indebted to chemiſtry. This ſalt is emetic, purgative, diuretic, diaphoretic, according to the doſes and proceſſes employed for its adminiſtration. Many a time it produces all theſe effects at once. It ſhould be regarded alſo as a powerful alterative, and a proper remedy in overcoming conſtipations and obſtructions of the viſcera, when it is given in very ſmall quantity frequently repeated. It is adminiſtered in the doſe of a grain to four grains, diſſolved in a proper vehicle, as an emetic. It is mixed in the doſe of a grain with other purgatives, which it aſſiſts; and in that of half a grain, largely diluted, as a good alterative. M. de Laſſone found, that tartar emetic is rendered very ſoluble in water by the addition of ſal ammoniac, and that a mixt ſalt reſults reſembling ſal alembroth.

This new compound ſhould be reckoned capable of producing very powerful effects upon the animal œconomy. Tartarus chalybeatus, martial ſoluble tartar, tartariſed tincture of Mars, are employed as tonic and aperient.

LECTURE LVI.

Of the ACID FERMENTATION *and of* VINEGAR.

MANY vegetable ſubſtances are ſuſceptible of undergoing the acid fermentation: ſuch are, the gums, the amylaceous feculæ, diſſolved in boiling water: but this property is very remarkable, in particular, in the fermented and ſpirituous liquors. All theſe liquors expoſed to heat, and in contact with the air, paſs to the acid fermentation, and yield the fluid called *vinegar*. It is eſpecially the wine of grapes which is employed for its preparation, although very good vinegar may be made from cyder, perry, &c.

There are three conditions requiſite in the acetous fermentation: 1. A heat of twenty or twenty-five degrees of Reaumur's thermometer: 2. A viſcous and at the ſame time acid body, ſuch as a mucilage and tartar: 3. The contact of air. The change of wines which paſs to the ſtate of vinegar, is to be aſcribed only to the inteſtine motion excited in theſe fluids by the preſence of a certain quantity of a mucous body not altered, and capable of undergoing a new fermentation. The preſence of an acid matter, ſuch as tartar, is neceſſary to determine the acid fermentation. Laſtly, the contact of the air is indeſpenſable; and it appears that there is a portion of it abſorbed during this fermentation, as M. l'Abbé Rozier has proved.

All wines are equally proper to form vinegar. The worſt of them are preferred, becauſe they are cheaper; but the experiments of Becher and Cartheuſer demonſtrate, that the generous wines, and thoſe abounding in ardent ſpirit, yield in general the beſt vinegars.

Boerhaave, in his Elements of Chemiſtry, has deſcribed a very good proceſs for the formation of vinegar. Two barrels are taken, and a hurdle of twigs placed at ſome diſtance from their bottom, upon which are extended vine branches and ſtalks; ſome wine is poured upon them, ſo that one of the barrels is full and the other half empty. The fermentation commences in this laſt: when it is ſet agoing, this barrel is filled with the wine contained in the firſt. By this means the fermentation ſtops ſhort in the full veſſel, and is well forwarded in that which is half empty. When it has advanced to a conſiderable degree, this laſt barrel is filled with the liquor of that which fermented the firſt time; ſo that the fermentation recommences in the firſt and ſtops ſhort in the ſecond. Thus the two barrels are alternately filled and emptied till the vinegar be entirely formed; which happens generally in twelve or fifteen days.

Upon obſerving what paſſes in this fermentation, much bubbling and hiſſing is perceived; the liquor is heated and troubled; it exhibits a great number of filaments, which run through it from all ſides; it emits a very acid ſmell, not at all dangerous; it abſorbs a great quantity of air: the fermentation muſt be ſtopped twelve of the twenty-four hours. Theſe phenomena gradually abate, the heat diminiſhes, the motion ſtops, the liquor becomes clear; it lets fall a ſediment in reddiſh ſlimy flocci, which ſtick to the ſides of the barrels. Numerous experiments have taught us, that the ſmaller the quantity of wine the fuller is the contact of air, and the more quickly it paſſes to the ſtate of vinegar. Care is taken to draw off the vinegar clear when it is made, in order to ſeparate it from above its lee; which without this precaution would make it paſs to the putrid fermentation. Vinegar does not depoſite tartar as wine does. This ſalt is diſſolved and combined with the ardent ſpirit and water during the fermentation; it is even probable that it is the preſence of this ſalt which contributes to the taſte and the other acid properties of vinegar. This fluid has more or leſs colour, according to the wine employed in its preparation: but in general, the leaſt coloured vinegars are much more ſo than the white ones; becauſe they hold diſſolved the colouring matter of the tartar, which has been alſo evolved in the fermentation *.

Vine-

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* When the acetous fermentation is completely finiſhed, and all the wine converted into vinegar, we are no longer able to diſcover any veſtige of the ardent ſpirit which the wine contained, or to extract a ſingle drop of it from old vinegar by diſtillation; the inflammability, along with all the other properties of the ſpirit of wine,

Vinegar prepared as juſt now deſcribed, is very fluid, of an acid and ſpirituous odour, of a more or leſs ſtrong bitter taſte: it reddens the blue colours of vegetables. Expoſed to a gentle heat in veſſels ſlightly ſhut, it is altered, loſes its ſpirituous part, depoſites a great quantity of mucous tufts and filaments, and aſſumes a putrid ſmell and taſte. It appears to be a compound of water, ardent ſpirit, a particular acid, a little tartar, and a colouring extractive matter. Theſe matters

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wine, being totally loſt or deſtroyed by the progreſs of the fermentation, and never to be recovered again by the employment of any proceſs with which we are acquainted: But the vinegar cannot be reſtored to the ſtate of wine; it has a natural tendency to proceed towards the putrefactive fermentation, and to loſe all its diſtinguiſhing qualities, and to be no longer acid. This diſpoſition to change proves frequently troubleſome to vinegar-brewers. The progreſs of the fermentation may however be ſtopped by quenching a red hot iron in the liquor; and the acidity may be again imparted by the addition of ſome ſpirit of wine. So that the ſtrength of the vinegar ſeems in ſome meaſure to depend upon the quantity of ardent ſpirit which the wine contains. In confirmation of this, M. Cartheuſer obſerves, that vinegar becomes ſtronger when ſome ſpirit is put into the fermenting mixture: and Becher remarks, that by corking up a bottle cloſe, and uſing a greater degree of heat, he produced a ſtronger and better vinegar than what is to be made in the common way. But the ſtrongeſt of all vinegars is procured by decompoſing ſome neutral ſalt by means of heat, as Mr Fourcroy has explained. There is, however, another method of concentration practiſed in convenient ſituations. This method is to expoſe the acid to a cold mixture, when the aqueous part congeals, and leaves the acid ſtill fluid. By expoſing this concentrated acid to a ſtill greater degree of cold, ſome more of the water is ſeparated; and by repeating this mode of procedure ſufficiently often, the vinegar may at laſt be brought to about ſeven times its original ſtrength, according to the experiments of M. Geoffroy. Vinegar in this ſtate is perhaps in ſome reſpects nearly as ſtrong as ſome of the weaker mineral acids, eſpecially the marine. But however much concentrated, it differs from all of them in the extreme degree of volatility; for in place of attracting humidity from the air, it flies off by expoſure, and is entirely diſſipated: and when united to a metallic, earthy, or ſaline baſis, the ſalt may be decompoſed, and the vinegar expelled, by means of heat alone; which is not the caſe with neutral ſalts formed by the mineral acids.

may be ſeparated by the action of the fire, as wine is done.

In diſtilling vinegar in a naked fire in a cucurbit of free-ſtone covered with a head, or in a glaſs retort placed upon a ſand bath, at firſt a phlegm of a briſk agreeable odour paſſes over, but very ſlightly acid; to it very ſoon a very white acid liquor ſucceeds, having a fragrant ſmell. This is diſtilled vinegar; what diſtils after that has leſs ſmell and more acidity: it becomes the more acid as the diſtillation advances. All theſe products may be ſeparated, and diſtilled vinegars obtained, differing from one another in acidity and ſmell. About two thirds of liquor, which conſtitutes the pureſt vinegar, are ſufficient to be drawn over in this proceſs. The portion which comes over after that, is more acid, but has an empyreumatic ſmell, which may be diſſipated by expoſition to the air: it aſſumes alſo a ſmall colour. This operation ſhows, that the acetous acid is heavier than water; the remaining vinegar is thick, of a deep and dirty red colour: it depoſites a certain quantity of tartar; it is conſiderably acid. If it is evaporated in an open fire, it aſſumes the form of an extract: and if, when it is dry, it is diſtilled in a retort, it affords a reddiſh acid phlegm; an oil, at firſt light and coloured, and after that weighty; and a little volatile alkali: the coal which is left contains much fixed alkali.

Vinegar may be concentrated by expoſition to a congealing heat. It is then obſerved to be very acid, and copious in colour, but very eaſily altered.

The acid of vinegar, ſeparated from tartar and from its colouring part by diſtillation, is ſuſceptible of uniting with a great number of bodies.

It combines but imperfectly with argillaceous earth, and forms with it ſmall needled cryſtals.

It unites eaſily with magneſia, and yields a ſalt very ſoluble in water, uncryſtalliſable, but which furniſhes by evaporation a viſcous deliqueſcent maſs. This ſalt is decompoſed by heat and the mineral acids: it is very ſoluble in ſpirit of wine.

The acid of vinegar combines with lime, and it decompoſes chalk, diſſipating its acid. This ſalt which it forms with lime, is ſuſceptible of cryſtalliſing into very fine needled priſms like ſatin. Calcareous acetous ſalt is bitter, ſour, efflореſcent, and decompoſable by fire and the alkalis.

The combination of vinegar with the vegetable alkali is called *terra foliata tartari.* It is made by pouring upon white ſalt of tartar very pure diſtilled vinegar; the mixture is agitated, and vinegar added, to the point of ſaturation and ſolution of the ſalt; even an exceſs of acid ſhould be added: the liquor is filtrated, and evaporated with a very gentle fire in a porcelain or pure ſilver veſſel; when it becomes thick, the evaporation is continued in a ſand-bath till the ſalt be very dry. By this means a very white terra foliata is obtained. If it is too much heated, it acquires a grey or brown colour, becauſe a portion of the vinegar is burnt. Some chemiſts ſay, that this ſalt may be obtained in a regular form, by leaving the ſolution to cool when evaporated to a thick pellicle. The terra foliata tartari has a pungent, acid, and urinous taſte. It is decompoſable by the action of the fire, and yields in a retort an acid phlegm, an empyreumatic oil, ſome volatile alkali, and a great quantity of a fragrant gas, formed of aërial acid, and inflammable gas. The remaining coal contains much uncombined fixed alkali. This ſalt ſtrongly attracts the air's humidity; it is very ſoluble in water. Vitriolic acid decompoſes it. This decompoſition is effected by pouring upon two parts of terra foliata, introduced into a tubulated glaſs retort, to which a recipient is adapted, one part of oil of vitriol: a vapoury fluid is inſtantly diſengaged with a briſk effervеſcence, of a penetrating ſmell, which condenſes in the receiver in form of a liquor called *radical vinegar.* This vinegar is very concentrated, of a very ſtrong acidity; but it is not pure, and is always mixed with a certain quantity of ſulphureous acid, diſtinguiſhable by its ſmell. Cream of tartar likewiſe decompoſes it, and forms with its baſe vegetable ſalt.

Vinegar unites perfectly with marine alkali, and forms with it a ſalt called *acetous mineral ſalt.* This ſalt differs from terra foliata only in being more ſuſceptible of cryſtalliſing in ſtriated priſms, very ſimilar to Glauber's ſalt, and in being not deliqueſcent.

In order to obtain it well cryſtalliſed, its ſolution muſt be evaporated till a pellicle appear on the ſurface, and then ſet in a cool place. The acetous mineral ſalt is decompoſable by the fire and the mineral acids, like the terra foliata. To theſe details we ſhall add, that when a ſtrong fire is added in diſtilling the acetous calcareous and alkaline ſalts, the reſidua of theſe ſalts are ſo many pyrophori, and burn when expoſed to the air. M. Prouſt, to whom theſe diſcoveries are owing, is of opinion, that to produce a pyrophorus, only a charry reſiduum is required, divided by an earth or a metallic calx.

Acid of vinegar forms with volatile alkali a ſalt called *ſpirit of Mindererus.* This ſalt cannot be evaporated without loſing the greateſt part of it on account of its volatility; however, by a long evaporation, needled cryſtals are obtained, whoſe taſte is hot and pungent, and which attract very readily the air's humidity. This acetous ammoniacal ſalt is decompoſed by the action of heat, by lime and the alkalis, which diſengage its volatile alkali; and by the mineral acids, which diſlodge its acid.

Vinegar acts upon almoſt all the metallic ſubſtances; and in theſe combinations preſents very important phenomena.

It does not ſeem to diſſolve immediately calx of arſenic: but this ſubſtance, diſtilled with equal parts of terra foliata, yielded to M. Cadet and Meſſieurs the Dijon Academicians a red fuming liquor, of a very ſtinking ſmell, very tenacious, and of a very ſingular nature. M. Cadet has already obſerved, *Acad. des Sciences, Savans Etrangers, tom.* 2. *p.* 633. that this liquor was capable of kindling fat lute. Meſſieurs the Dijon Academicians, deſirous to examine a yellowiſh matter of an oily conſiſtence collected at the bottom of the veſſel, which contained the arſenico-acetous fuming liquor, decanted a portion of this ſupernatant liquor, and poured the reſt upon filtrating paper. Scarce had a few drops paſſed through when a very diſagreeable ſmoke inſtantly aroſe, which formed a column from the veſſel to the ceiling; a kind of boiling was excited at on the ſides of the matter, and a beautiful roſy flame iſſued out, which continued for a few inſtants.

In the third volume of the Dijon Elements of Chemiſtry, p. 41—47. the detail may be ſeen of the beautiful experiments which theſe learned academicians made upon the ſubject. They compare this liquor to a liquid phoſphorus: we think it is a kind of pyrophorus, like theſe, which we ſhall deſcribe more fully afterwards. The reſiduum of the terra foliata with the calx of arſenic, is in great meaſure vegetable fixed alkali.

Vinegar diſſolves the calx of cobalt, and forms a pale roſe-coloured ſolution.

It has no action upon biſmuth or its calx.

It directly diſſolves nickel, according to M. Avidſon. This ſolution yields green cryſtals formed in ſlices.

This acid does not act upon regulus of antimony; but it ſeems to diſſolve the glaſs of this ſemimetal, as Angelus Sala prepared an emetic ſalt with theſe two ſubſtances.

Zinc, and likewiſe its calx, diſſolves very well in diſtilled vinegar. M. Monnet obtained from this ſolution, when evaporated, flat laminated cryſtals. The acetous ſalt of zinc fulminates upon coals, and emits a ſmall blueiſh flame. To diſtillation it yields an inflammable liquor, a yellow oily fluid, which becomes very ſoon of a deep green, and a white ſublimate, which burns in the light of a candle with a beautiful blue flame. The reſiduum is in the ſtate of a pyrophorus which is not very combuſtible.

Acid of vinegar does not diſſolve mercury in its metallic ſtate. However, this combination is effected by minutely dividing the metal by means of mills, as Keyſer did. Calx of mercury eaſily unites with vinegar. This acid is boiled upon precipitate *per ſe*, upon turbith, or upon the mercury precipitated from the nitrous ſolution by the fixed alkali. The liquor becomes white, and when it boils clear it is filtrated; it precipitates by cooling ſpangled argentine cryſtals, reſembling ſedative ſalt. This ſalt has been called *terra foliata mercurialis*. It is at once prepared by pouring a nitrous ſolution of mercury into one of terra foliata tartari: the nitrous acid unites with the fixed alkali of this laſt, with which it forms nitre, which remains in ſolution in the liquor; and the calx of mercury combined with the vinegar is precipitated in the form of brilliant ſpangles: the mixture is filtrated, the terra foliata mercurialis remains upon the filtre. This ſalt is decompoſed by the action of the fire: its reſiduum yields a kind of pyrophorus. It is eaſily altered by combuſtible vapours.

Tin is but very little altered by vinegar. This acid diſſolves but a very ſmall quantity of it; and the ſolution evaporated yielded M. Monnet a yellowiſh pellicle, reſembling gum, and of a fetid odour.

Lead is one of the metals upon which it has the moſt action. This acid diſſolves it with the greateſt facility. This metal in laminæ, expoſed to the action of hot vinegar, is covered with a white powder called *ceruſs*, which is only a calx of lead. This calx bruiſed with a third of chalk, forms the white-lead of the painters. In order to ſaturate vinegar with as much lead as it can diſſolve, this acid is poured upon the ceruſs in a matraſs; the mixture is ſet to digeſt in a ſand-bath; the liquor is filtrated after ſeveral hours digeſtion; it is evaporated to a pellicle; it furniſhes by cooling and repoſe white cryſtals, forming either ſhapeleſs needles, if the liquor has been too much evaporated, or flattened parallelopipeds terminated by two ſurfaces, diſpoſed like the top of a houſe, when the operation has been properly conducted. They are called *ſalt* or *ſugar of lead*, on account of its ſaccharine taſte; this taſte is at the ſame time ſtyptic. A ſimilar ſalt is prepared with litharge and vinegar: equal parts of theſe two ſubſtances are boiled together till they be ſaturated; the liquor is evaporated to the conſiſtence of a clear ſyrup: in this ſtate we have Goulard's extract of lead, known long before him by the name of *vinegar of lead.* Saccharum ſaturni is decompoſed by heat; it furniſhes an acid, reddiſh, very fetid liquor, very different from radical vinegar. The reſiduum is a very fine pyrophorus. This ſalt is decompoſed by diſtilled water, lime, alkalis, and mineral acids. The extract of lead, diluted with water and mixed with a little aquavitæ, forms Goulard's vegeto-mineral water.

Vinegar diſſolves iron with activity. The efferveſcence which happens in this ſolution is owing to the diſengagement of an inflammable gas, whoſe properties have not been examined. The liquor aſſumes a red or brown colour. By evaporation it yields only a gelatinous magma, mixed with a few brown elongated cryſtals. This martial acetous ſalt has a ſtyptic ſweetiſh taſte; it is decompoſed by the fire, and lets go its acid; it attracts the air's humidity; it is decompoſed in diſtilled water. If it is heated till it emit no more ſmell of vinegar; it leaves a yellowiſh calx attractible by the magnet.

The acetous ſolution of iron yields a very black ink with the gall-nut; and it might be employed with ſucceſs in the tincture. The Pruſſian alkali precipitates from it a very pretty Pruſſian blue. Martial æthiops, the precipitates of iron, the croci of Martis, the ſparry ore of iron, yield with vinegar ſolutions of a very beautiful red.

Copper diſſolves with great facility in diſtilled vinegar. This ſolution, aided by heat, gradually aſſumes a green colour; but it is more eaſily effected with this metal already altered and calcined by vinegar. Copper thus prepared is verdegris. It is prepared about Montpelier, by putting laminæ of this metal into earthen veſſels with grape ſtalks, which have been firſt moiſtened and fermented. The ſurface of theſe laminæ is very ſoon covered with a green ruſt, which is alſo augmented by heaping them together; then the copper is ſcraped, and the verdigris ſhut up in leather ſacks and ſent to market. M Monnet, an apothecary at Montpelier, has fully deſcribed this manipulation in two papers printed among thoſe of the Academy of Sciences 1750-3. Verdegris diſſolves with readineſs in vinegar. This ſolution, which is of a beautiful green colour, furniſhes by evaporation and cooling green cryſtals in quadrangular truncated pyramids, which he calls *verdigis*, or *cryſtals of Venus*.

Thoſe which are prepared in commerce, and called *diſtilled verdigris*, becauſe they are prepared with diſtilled vinegar, are in the form of a beautiful pyramid: its cryſtals preſent this arrangement, becauſe they are depoſited upon a rod cleft into four, whoſe branches have been ſeparated by a piece of cork.

Verdigris has a very ſtrong taſte, and is a violent poiſon. It is decompoſed by the action of the fire; it is efflorescent, and is covered with a powder whoſe green colour is much more pale than that which diſtinguiſhes this ſalt when not altered: it diſſolves completely in water without being decompoſed. Lime-water and the alkalis precipitate this ſolution.

When this ſalt, in powder, is diſtilled in a glaſs or earthen retort with a recipient, a fluid, at firſt white and a little acid, is obtained, but which very ſoon acquires a conſiderable acidity, and ſuch as equals the concentration of the mineral acids. The retort is changed to have ſeparately the phlegm and the acid. This is called *radical*

dical vinegar or *vinegar of Venus*. This acid is coloured green by a certain quantity of calx of copper, which carries over in the diſtillation. When no more paſſes and the retort is red, the reſiduum which it contains is in the form of a brown powder of the colour of copper, which frequently communicates the brilliancy of this metal to the ſides of the retort. This reſiduum is ſtrongly pyrophoric, as Meſſrs le Duc d'Ayen and Prouſt have obſerved. Vinegar of Venus is rectified by diſtilling it with a gentle heat; then it is perfectly white, provided the fire is not urged too far towards the end of the operation, and the portion of calx of copper remaining in the retort not too much dried.

Radical vinegar, thus rectified, has a ſmell ſo pungent and penetrating, that it is impoſſible to endure it any time: its cauſticity is ſo great, that when applied to the ſkin it reddens and corrodes it. This fluid is conſidered as the moſt pure acid of vinegar, the moſt concentrated and free of the phlegm which covered its properties. This acid is extremely volatile and inflammable; heated with the contact of air it kindles and burns ſo much the more rapidly the higher the ſtate of rectification. This experiment led chemiſts to believe that vinegar is an acid combined with ardent ſpirit; perhaps it might even be conſidered as a kind of natural ether. This idea agrees with the penetrating and agreeable odour which the firſt diſtilled portions of this acid emit. Radical vinegar evaporates entirely in the air; it unites with water, and produces great heat; it forms with the earths, alkalis, and metals, the ſame ſalts with ordinary vinegar; but it acts upon combuſtible bodies, generally much more remarkably than this laſt. M. le Marquis de Courtanvaux, *Acad Savans Etrangers*, vol. 5. p. 72. that it was only the laſt portion of acetous fluid, obtained in the diſtillation of verdigris, which was inflammable; and that it poſſeſſed alſo the property of congealing by cold. This laſt portion, rectified, cryſtalliſed in the recipient in large laminæ and needles; and returns to its fluid ſtate only when expoſed to a heat of thirteen or fourteen degrees above the freezing point. This liquor is a kind of glacial vinegar.

The acid of vinegar, aided by heat, diſſolves gold precipitated by the fixed alkali. This ſolution precipitated by the volatile alkali yields fulminating gold, as demonſtrated by M. Bergman. The ſame thing happens to platina and gold: they are both diſſolved. Radical vinegar has no action upon theſe metals in a metallic ſtate, but diſſolves them in the ſtate of a calx.

Vinegar is ſuſceptible of combining with ſeveral of the immediate principles of vegetables; it diſſolves the extracts, mucilages, and eſſential ſalts; it unites with the ſpiritus rector; it has been conſidered as the proper ſolvent of gum-reſins; it has through length of time or by diſtillation alſo a very remarkable action upon the fat oils, which it converts into a kind of ſoapy ſtate: the combination of vinegar with vegetable ſubſtances has not yet been examined. This acid is made uſe of to extract ſome of the principles, and particularly the odour of theſe bodies; and vinegars of different natures ſimple or compound, are prepared in medicine. Acetum ſcilliticum, colchicum, afford an example of the firſt kind; theriacal vinegar belongs to the ſecond. Theſe medicines are prepared by continued maceration and digeſtion for ſeveral days. As this acid is volatile, it is diſtilled upon aromatic plants, whoſe odorous principle it attracts; ſuch is the diſtilled vinegar of lavender, which is employed for the toilette. Theſe liquors are in general leſs agreeable than the ſpirituous diſtilled waters.

Radical vinegar decompoſes ſpirit of wine, and forms ether with as much facility as the mineral acids, as diſcovered by M. le Count de Lauraguais. For this purpoſe, radical vinegar is poured into a retort upon an equal part of ſpirit of wine; a conſiderable heat is produced; the retort is put in a hot ſand-bath, and two recipients are adapted, the laſt of which is plunged into cold water or pounded ice; the mixture is made to boil quickly. At firſt a dephlegmated ſpirit of wine paſſes over, then the ether, and at laſt an acid, which turns ſtronger as the diſtillation advances; a brown maſs reſembling a reſin remains in the retort. Care is taken to change the recipient as ſoon as the etherial ſmell turns acrid and pungent, and the acid is collected apart. The ether is rectified with a gentle heat with cauſtic fixed alkali, and a great deal of it is loſt in this operation.

M. de la Planche an apothecary, prepared this ether by pouring upon ſaccharum ſaturni, introduced into a retort, oil of vitriol and ſpirit of wine. The theory and practice of this operation correſpond with thoſe made uſe of in preparing the marine, nitrous, and vitriolic ethers.

Acetous ether has an agreeable ſmell like the other ethers; but it is always mixed with that of vinegar, although it is not acid. It is very volatile and inflammable; it burns with a vivid flame, and leaves a charry mark after its combuſtion.

Vinegar is employed as a ſeaſoning to meat. Much uſe is made of it in medicine; it is refrigerant and antiſeptic; with ſugar a ſyrup is made of it, which is given with great ſucceſs in ardent and putrid fevers; applied externally it is aſtringent and reſolvent. All its combinations are uſed likewiſe as very good medicines.

Terra foliata tartari and acetous marine ſalt are powerful deobſtruents and aperients: they are adminiſtred in the doſe of half a gros, and even a gros.

Spirit of mindererus, given in a few drops in convenient vehicles, is aperient, diuretic, cordial, antiſeptic. It does ſervice frequently in leucophlegmaſias or ſwellings of the external parts of the body.

The terra foliata mercurialis is a very good antivenereal: it made the baſe of Keyſer's pills.

The extract of lead, acetum ſaturni, aqua-vegeto-mineralis, are employed externally as diſcutients: theſe me-

medicines being ſtrong repellents ought to be be adminiſtred with great prudence; particularly when applied to the ſkin upon uncovered ulcerated parts. Boerhaave met with ſeveral girls ſeized with phthiſis after the external uſe of the preparations of lead.

Ceruſs enters the compoſition of drying ointments and plaſters, and verdigris compoſes ſeveral collyria and ointments.

Radical vinegar is employed as a very powerful ſtimulent like the volatile alkali. It does ſervice in caſes of debility, when it is reſpired. To have it in a commodious form, a certain quantity of it is poured upon groſsly powdered vitriolated tartar, which is put into a veſſel well ſhut. This medicine is every where known by the name of *ſal aceti.*

Acetous ether has not yet been much uſed; and it is uncertain if it has any other virtues which the other ethereal liquors do not poſſeſs.

Of the Putrid Fermentation of Vegetables.

ALL vegetable bodies which have undergone the ſpirituous and acid fermentations, are ſtill ſuſceptible of a new inteſtine motion, which alters their nature. This motion is called the *putrid fermentation.* Stahl and ſeveral other chemiſts have ſuppoſed that this ſpecies of fermentation is only a continuation of the two former; or rather, that theſe three phenomena depend only upon a ſingle indvidual motion, which tends to deſtroy the texture of the ſolids and to change the nature of the fluids: and indeed it is obſerved, that if certain vegetable ſubſtances are left to themſelves, they ſuffer the three fermentations ſucceſſively and without interruption. For inſtance, all the ſaccharine matters, diluted with a large quantity of water, and expoſed to a degree of heat from twelve to twenty degrees, yield, firſt wine, then vinegar, and at length their acid character is very ſoon loſt; they are altered, putrify, loſe all their volatile principles, and finiſh with leaving only a dry, inſipid, earthy ſubſtance. However, it muſt be obſerved, tha a great number of vegetable ſubſtances do not undergo, at leaſt in a ſenſible manner, theſe three kinds of fermentations in the order mentioned The taſteleſs mucilages, the gums diſſolved in water, paſs to the acid ſtate without becoming manifeſtly ſpirituous: the glutinous matter ſeems to paſs directly to putrefaction without having been aceſcent. It appears, therefore, that though, in ſeveral principles of vegetables, theſe three fermentations follow and ſucceed each other, there is, however, a great number of others which are ſuſceptible of undergoing the two laſt and not the firſt, or even the putrefactive ſtate, without having manifeſted any ſigns of acidity.

The inteſtine motion, which changes the nature of vegetable ſubſtances, and reduces them into their elements, requires particular conditions, which it is neceſſary to know. Humidity, or the preſence of water, is one of the moſt neceſſary: the dry and ſolid vegetables, ſuch as wood, are not at all altered as long as they retain this ſtate; but if they are moiſtened, and their fibres divided, then the inteſtine motion very ſoon begins. Water, then, appears to be one of the cauſes of putrefaction. Heat is not leſs neceſſary. Cold, or the freezing point, not only oppoſes this ſpontaneous deſtruction, but it even retards its progreſs, and forces theſe ſubſtances which have been influenced by it to take as it were a retrograde motion. The degree of heat neceſſary to putrefaction is much leſs than that which the acid and ſpirituous fermentations ſupport, as this phenomenon begins at the temperature of five degrees; but a more conſiderable heat is better, one at leaſt ſo weak as not to diſſipate the moiſture and entirely dry the ſubſtance which is putrefying. The acceſs of air is alſo a condition which ſingularly favours putrefaction, as vegetable ſubſtances are kept very well *in vacuo*. However, this preſervation is limited; and the contact of air does not ſeem to be ſo indiſpenſable to the putrid fermentation as the two conditions mentioned before.

The putrefaction of vegetables has its particular phenomena. Vegetable fluids which are putrefying, are troubled, loſe their colour, depoſite different ſediments; air-bubbles riſe to their ſurface, and mouldy tufts form in its beginning. Vegetable ſubſtances ſimply moiſtened, and thoſe which are ſoft, exhibit the ſame phenomena. The motion which is here exerted is never ſo conſiderable as that by the ſpirituous and acid fermentations. The volume of the ſubſtance which is putrefying does not appear to be augmented, nor its heat increaſed; but the moſt important phenomenon is the change of ſmell and the volatiliſation of an acrid, pungent, urinous principle, reſembling the volatile alkali, and which in fact is it: hence putrefaction has been called the *alkaline fermentation*, and the volatile alkali has been conſidered as its product. The pungent odour gradually exhales, a nauſeous inſipid odour ſucceeds, which it is difficult to deſcribe. In this ſtate the decompoſition is at its height; the putrefied vegetable is very ſoft, like thick milk; it ſuffers a great number of ſucceſſive modifications in the odorous principle, which it exhales: in the laſt place, it dries; its diſagreeable odour gradually diſſipates, and it leaves only a blackiſh, as if charry, reſiduum, in which only a few ſaline and earthy ſubſtances can be found.

Such is the order of the phenomena which are obſerved in the ſpontaneous decompoſition of vegetables which are putrefying; but this decompoſition, puſhed to the point of reducing them to their earthy or ſaline ſtate, is very tedious in its performance; and it ſhould be alſo added, that it has not been properly obſerved by any perſon. Naturaliſts and chemiſts have been reproached for their neglect with reſpect to animal-ſubſtances; but they are more deſervedly blamed for their neglect of vegetables. No intelligent perſon has yet undertaken to obſerve the complete putrefactio of theſe, although many have deſcribed the phenomena which happen in that of animal-matters. Upon this account we think, that the hiſtory of the ſpontaneous and natural analyſis of vegetables ſhould now be concluded ; adding only, 1. That the little which has been ſaid is ſufficient to ſhow, that vegetable putrefaction attenuates, volatiliſes, and deſtroys all the humours of theſe bodies, and reduces them to the earthy ſtate. 2. That nothing yet is poſitively known of the phenomena and limits of this kind of putrefaction, properly to warrant its diſtinction from that of animal-matters. 3. As this fermentation is much more remarkable, and has been more obſerved in the humours and ſolids of animals, the details, which we ſhall add at greater length in the examination of theſe ſubſtances, ſhall complete the ſketch which we have juſt now given, and ſhall terminate the hiſtory of the facts known upon putrefaction, which intereſts eſpecially young phyſicians, for whom this part of our work is particularly deſigned.

ANIMAL KINGDOM.

LECTURE LVII.

Natural Hiſtory of ANIMALS *.

ANimals are in general diſtinguiſhed from vegetables by loco-mobility and more perfect organiſation. However, there are ſome entire claſſes of theſe ſubſtances that are fixed to one place like vegetables; as the lithophytes, the zoophytes, known by the name of *polypi*, which are born and die upon the ſame ſoil: And on the other hand, ſome vegetables exert as much motion in their leaves and flowers as certain animals; for inſtance, the cruſtaceous worms. Organiſation appears even leſs perfect in the polypi than in the moſt part of plants. It hence follows, that it is very difficult to eſtabliſh an exact line of ſeparation between theſe two kingdoms; and naturaliſts have been neceſſarily obliged to confound them into one, known by the name of *Organic Kingdom*.

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* We propoſe to give here only a ſummary of the methods of the naturaliſts, to facilitate to beginners the ſtudy of natural hiſtory and the underſtanding of good authors. As to the general conſiderations about the nature of animals, the order which we have adopted does not permit us to enter into details upon this ſubject, eſpecially when treated in ſo excellent and philoſophical a manner by M. le Comte de Buffon and M. Bonnet.

However, upon conſidering only perfect animals, great differences are found between theſe ſubſtances and vegetables. Numerous and very diſtinct organs, a more complicated ſtructure, more numerous and extenſive functions, are the characters to which theſe differences ſhould be deſcribed; notwithſtanding, it is not the leſs difficult to give a good definition of theſe ſubſtances.

Confining ourſelves to the moſt general characters, animals may be defined to be bodies endued with underſtanding and motion, faculties neceſſary for the preſervation of their life. All can be reproduced; ſome, by the union of the two ſexes, bring forth living young ones; others lay eggs, which require only heat to bring forth the young; there are ſome which are multiplied without the aſſiſtance of their mates; laſtly, ſeveral are reproduced when they have been cut, as is done with the roots of plants.

It is very difficult for naturaliſts to aſſign to animals the true character of their kind. The mixture of races produces varieties without number: tranſportation into different climates alſo occaſions various changes in form, in colours, &c. Thoſe only whoſe form is conſtant, and which are perpetuated by the reproduction of the individuals, ſhould therefore be accounted as diſtinct kinds. With regard to the alterations produced by the growth of the ſpecies, the climate, and cohabitation, they ought to conſtitute only varieties.

The number of animals which cover the ſurface of our globe being very conſiderable, man never would have arrived at diſtinguiſhing and recogniſing each of them, had not nature preſented, in the diverſified form of the external parts of their bodies, remarkable differences, by means of which it was eaſy for him to eſtabliſh the diſtinctions. Naturaliſts have at all times felt the utility of theſe differences, and have made uſe of them with advantage in dividing animals into more or leſs numerous claſſes, and forming what are called *methods*. Although it be demonſtrated, that theſe kinds of claſſifications do not exiſt in nature, and that all the individuals which nature produces form an uninterrupted chain without diviſion, it cannot, nevertheleſs, be denied, that they aid the memory, and are very proper to guide our ſtudy of natural hiſtory. The methods, then, ought to be conſidered as inſtruments appropriated to our weakneſs, which may be employed with vaſt ſucceſs in taking a ſuperficial view of the vaſt field of the riches of nature. Ariſtotle eſtabliſhed only general and ſimple diviſions; but his excellent reflections upon the external and internal organs of animals have formed a baſe upon which in a great meaſure have been founded the diviſions of the firſt methodical naturaliſts, ſuch as Geſner, Aldrovand, Johnſton, Charleton, Ray, &c. A great number of other naturaliſts ſucceeded theſe, who have completed the methods, and who have added to the knowledge acquired in this department of ſcience; but among theſe laſt, thoſe whoſe works it is neceſſary to be well acquainted with, and from whom we ſhall borrow what we are to ſay here, are Meſſrs Klein, Linnæus, Briſſon, Geoffroy, &c.

After man, whoſe organiſation and underſtanding require that he ſhould be ſet at the head of animal bodies, and which makes him alone one claſs apart, all the other animals may be divided into eight claſſes; which are, the quadrupeds, the cetaceous animals, birds, amphibious animals, fiſhes, inſects, worms, and polypi. Perhaps it might be poſſible to multiply theſe claſſes: but then, by augmenting the diviſions, the difficulties would be multiplied; and this is what muſt be avoided in the artificial method, whoſe ſimplicity and perſpicuity conſtitutes its only merit.

Claſs I. QUADRUPEDS. ZOOLOGY.

QUADRUPEDS are animals which have four feet, whoſe body is covered for the moſt part with hair:

they reſpire by means of lungs, ſimilar to thoſe of man; they have a heart, with two ventricles: they are viviparous. Theſe animals are thoſe whoſe ſtructure approaches moſt to man: there are ſome, as the ape and ſome others, which Linnæus thought might be confounded even in the ſame order with man. This naturaliſt gives the name of *mammalia* to this claſs of animals, in which he comprehends the cetacea; becauſe all theſe have dugs, and ſuckle their young.

Although this claſs of animals ſeems to approach to man, they are, however, very different; but it is requiſite to unite them here. The differences are the horizontal poſition of their bodies; the form of the extremities; thickneſs; the hardneſs of their ſkin, covered with hair or furniſhed with a hard ſhell, as if horny; the vertebral column, prolonged to form the tail; the anterior part of the cranium, flattened and horizontal; the ears, large and elongated; the bones of the noſe and upper jaw, very long, and placed obliquely. Upon comparing this ſtructure with that of man, whoſe body is erect and perpendicular, the radius of the arm is moveable, the fingers are fully ſeparated, the thumb is oppoſed to the four others, the ſkin is flecked and thin, it will ſoon be perceived how much this conformation exalts his ſenſibility, and renders him ſuperior to the moſt perfect animals. The anatomy of his internal organs, and the hiſtory of his functions, alſo add much weight to theſe important conſiderations.

The ancient naturaliſts, at the head of whom may be placed Ariſtotle and Pliny, diſtinguiſhed quadrupeds only by the places which they inhabited. So, for want of exact deſcriptions and ſure characters, we are at a loſs ſometimes to diſcover what animals they are deſcribing. The naturaliſts, who perceived the diſadvantages of this method, adopted a very different manner of treating the ſubject. They made uſe of the external form of the moſt apparent parts of animals to render their characters eaſy to be underſtood, by means of which they might be ſurely diſtinguiſhed from one another. We ſhall relate here only three artificial methods with reſpect to quadrupeds; thoſe of Linnæus, Klein, and Briſſon.

Method of LINNÆUS.

LINNÆUS divides the animals with dugs, *Mammalia*, into ſeven orders. The firſt, which comprehends thoſe which he calls *primates*, has for characters, dentes inciſivi in both jaws; two mammæ, ſituated upon the breaſt; the arms extended from the clavicles. This order contains four genera, viz. man, the ape, proſimia, and veſpertilio. We cannot but ſay, that this method is far from being natural, as it approximates bodies of very diſtinct natures, as man and a bat.

Animals of the ſecond order are called *bruta*. Their characters are, the abſence of the dentes inciſivi, the feet armed with ſtrong claws, ſlow walking. This order comprehends ſix genera; which are, the elephant, trichecus, bradypus, myrmecophaga, manis, daſypus. The two firſt genera are very far diſtant from the four others.

In the third order, which the Swediſh naturaliſt deſigns by the name of *feræ*, wild beaſts, he comprehends all animals with mammæ, whoſe dentes inciſivi are conical; and for the moſt part ſix to both jaws, whoſe canini are very long, and molares not flat; whoſe feet are armed with ſharp claws; and, laſtly, which devour their prey, and live upon plunder. There are ten genera in this order; phoca, canis, felis, viverra, muſtela, urſus, didelphis, talpa, ſorex, and erinaceus.

The fourth order, intitled *glires*, is diſtinguiſhed by the following characters: The animals which compoſe it have two dentes inciſivi to each jaw, no canini; their feet are armed with claws, and proper for jumping. They eat bark, roots, &c. This order comprehends ſix genera; which are, the hiſtrix, lepus, caſtor, mus, ſciurus, and the American dormouſe, called by Linnæus *noctilio.*

This naturaliſt united in the fifth order, by the name of *pecora*, the quadrupeds which have dentes inciſivi to the inferior jaw, and which have none to the upper; whoſe feet are forked, and which are ruminant. Camelus, moſchus, cervus, capra, ovis, bos, are theſix genera which compoſe this order.

The ſixth order comprehends, under the name of *belluæ*, the quadrupeds which have obtuſe dentes inciſivi, and feet with claws. The four genera which compoſe this order, viz. equus, hippopotamus, ſus, rhinoceros, are diſtinguiſhed very well from one another by the number of their teeth and form of their feet.

Laſtly, the ſeventh order, which comprehends the *cetacea*, *cete*, is diſtinguiſhed from all others by the form of the feet, which reſemble fins. But as we ſuppoſe, with ſeveral modern naturaliſts, a particular claſs of cetacea ſhould be made, we ſhall treat of them after the quadrupeds.

The method of Linnæus appears to be defective in ſome points; not only in its approximating bodies ſo diſtinct as man and the bat, and in its ſeparating animals ſo ſimilar as the rat and the mouſe; but ſtill more ſo in the diviſions being not numerous enough, and in their not being fit for diſtinguiſhing a quadruped eaſily: now this ought to be the ſole merit of a method, and its only advantage.

Method of M. KLEIN.

M. KLEIN divided the quadrupeds into two great orders. In the firſt he has compriſed thoſe which have feet with claws, *pedes ungulati*, *pedes cheliferi*; in the ſecond thoſe whoſe feet have toes, *pedes digitati.*

The firſt order is divided into five families, whoſe character is taken from the diviſion of the pedes ungulati into ſeveral pieces. The firſt family, called *monochela*, comprehends the genus of the horſe. The ſecond, whoſe individuals are called *dichela*, comprehends all thoſe which have forked feet, *biſula*. Some have horns, as the bull, the ram, the goat, the ſtag, &c.; others have none, as the wild boar, ſow, babyrauſſa. The *trichela*, or animals whoſe foot is divided into three parts, compoſe the third family, in which there is only the rhinoceros. The fourth family, whoſe characteriſtic is to have the foot ſeparated into four pieces, *tetrachela*, contains only the hippopotamus. The fifth, which is diſtinguiſhed by the feet divided into five pieces, *pentachela*, contains only the elephant.

The ſecond order of quadrupeds, which comprehends thoſe which are *digitati*, is likewiſe divided into five families. The firſt, deſigned for the animals which have two toes to the foot, *didactyla*, comprehends the camel, and the ſilenus, or the ſloth of Ceylon. The ſecond family, in which are compriſed the animals with three toes to the feet, *tridactyla*, comprehends the ſloth and the ants. In the third, M. Klein compriſed under the name of *tetradactyla*, animals with four toes, the armadillos and the Guiney pigs, which ſeem to be kinds of rabbits. The fourth family, which has for characters five toes to the feet, *pentadactyla*: it is the moſt numerous of all; it contains the rabbit, ſquirrel, dormouſe, rat, mouſe, mole, bat, weaſel, porcupine, dog, wolf, fox, coati, cat, tyger, lyon, bear, ape: the number of the kinds comprehended under theſe different genera is very conſiderable. It muſt be obſerved, that M. Klein, in all theſe characters taken from the form of the feet, conſiders only the fore-feet for the diſtinction of the families. Laſtly, the fifth family of the *digitati*, is formed of the animals whoſe feet are irregular, *anomalopedia*, the otter, beaver, ſea-cow, and calf.

The ſame objection might be made to M. Klein's method as to that of Linnæus. Although his firſt diviſions are well adapted for families, the genera are not eaſy to be diſtinguiſhed according to his method, particularly thoſe of the fourth family of the digitati.

Me-

Method of BRISSON.

M. BRISSON has avoided the greateſt part of theſe inconveniences, by combining all the characters given by the naturaliſts who preceded him. The number of their teeth is made uſe of, their abſence, the form of the extremities, that of the tail, the nature of the appendices, as the horns, the ſcales, prickles. His combined method is without contradiction the moſt complete, and the moſt proper to diſtinguiſh a quadruped, and to refer it to the genus to which it belongs.

Claſs II. CETACEA.

THE cetacea are large animals which inhabit the ſea, and which, by the ſtructure of their lungs and of their blood-veſſels, may live in water, as we ſhall more fully relate in the hiſtory of reſpiration. They reſemble quadrupeds in the ſtructure of their mammæ, becauſe they bring forth their young alive, and in general in their internal organs: but they differ in the form of their extremities, which are formed into fins, and in two large openings placed at the top of their heads, by which they reject the water to a more or leſs conſiderable height. Naturaliſts call theſe conduits *ſpiracula.* The number of the genera of theſe animals is much leſs than that of quadrupeds. M. Briſſon diſtinguiſhed them, 1. Into cetacea which have no teeth; ſuch as the whale, balæna: 2. Into cetacea which have teeth only in the upper jaw; ſuch as the monodon or monoceros: 3. Into cetacea which have teeth only in the under jaw; ſuch as the phyſeter: 4. Into cetacea which have teeth in both jaws; ſuch as the dolphin, delphinus.

LECTRUE LVIII.

Claſs III. BIRDS. ORNITHOLOGY.

THE birds are two-feeted animals, which move in the air by means of their wings, which are covered with feathers, and which have a bill of a horny ſubſtance. Theſe animals preſent a great number of intereſting facts, relatively to the varied form of their bill, the ſtructure of their feathers, the motions which they make, their manners, &c. From the abridgement of phyſiology, which we ſhall offer in a more full manner afterwards, we ſhall learn the moſt important of theſe facts. We muſt confine ourſelves to the external characters, which naturaliſts have made uſe of to diſtinguiſh the birds, and to claſs them methodically.

The firſt philoſophers who treated of this part of natural hiſtory, eſtabliſhed no other differences between birds except which nature preſented, relatively to the places frequented by theſe animals. Thus they diſtinguiſhed them into birds of the woods, of the plains, buſhes, ſeas, rivers, lakes, &c. Some others have diſtinguiſhed them, by their way of feeding, into birds of prey, granivorous. &c.

But the methodiſts have followed another line to diſtinguiſh the birds. Linnæus has divided them, from the form of their bill, into ſix orders, like the quadrupeds, with which he compared them. But theſe diviſions ſeem to be not ſufficiently detailed, eſpecially in obſerving, that the number of the ſpecies is much more conſiderable in birds than in quadrupeds, as M. le Compte de Buffon has brought the number of known quadrupeds up to 200, and the birds to 1500 or 2000. We ſhall confine ourſelves to the methods of Meſſieurs Klein and Briſſon.

M. Klein divided the birds into eight families, from the form of their feet. The firſt, under the name of *didactyli*, comprehends thoſe which have two toes to the feet; the oſtrich is the only one in this diviſion. The ſecond comprehends the tridactyli; as the caſoar, the buſtard, the lapwing, the plover. The third, the tridactyli; thoſe which have two toes before and two behind; as the parrot, the wood-pecker, the cuckow, the king's-fiſher. The fourth, the tetradactyli which have three of their toes before and one behind. This family is the moſt numerous of all; it comprehends the birds of prey, diurnal and nocturnal, the corbies, magpies, ſtarlings, thruſhes, blackbirds, larks, &c. The fifth family comprehends the tetradactyli which have three toes before, united by a membrane, and the poſterior one is free. Theſe birds are called *plain footed;* the geeſe, ducks, gulls, puffings. The ſixth comprehends the tetradactyli whoſe four toes are united by one membrane: Theſe are called in Latin *planci.* The pelican, the cormorant, booby, &c. are ranked by M. Klein in this claſs. The ſeventh is compoſed of thoſe which have only three toes united by one membrane; theſe are the tridactyli palmipedes: the chaffinch, &c. belong to this claſs. Laſtly, the eighth comprehends the tetradactyli whoſe toes are furniſhed with membranes, fringed or fimbriated. They are alſo called *dactylobi.* The pigeons and moor-hens compoſe this laſt family. Klein's method, though more detailed than that of Linnæus, is ſtill pregnant with difficulties in diſtinguiſhing the genera, particularly thoſe of the fourth family. For this reaſon, we prefer that of M. Briſſon. It is true, that this laſt, in which the author has uſed all the characters united, as in the caſe of the quadrupeds, at firſt ſight appears very complicated; but upon being reduced into a table, all the diviſions are at once preſented, and from theſe any bird may be at once diſtinguiſhed.

Claſs IV. AMPHIBIOUS ANIMALS.

THE amphibious animals are thoſe which live upon land and water equally. They may remain in theſe a longer or ſhorter time. The toes of thoſe of theſe animals which have any toes, are almoſt always united by membranes; their ſkin is ſleek and ſcaly: ſometimes they are covered with an oſſeous ſhell. Some are oviparous; however, there are others that are viviparous; ſome ſwim, others walk as quadrupeds; laſtly, ſome creep like the worms. From theſe differences, Linnæus divided the amphibia into three orders. The firſt comprehends the reptiles which have feet; the ſecond the ſerpents; and the third the kinds of ſwiming animals called *cartilaginous fiſhes*.

LECTURE LIX.

Claſs V. FISHES. ICHTHYOLOGY.

FISHES are very different animals from the preceding, whoſe internal organs have a ſtructure quite particular, as we ſhall notice in our abridgement of phyſiology. They are diſtinguiſhed from other animals by their want of feet, but they have fins which ſerve to move them in the water; and by their reſpiring water inſtead of air. The fiſhes are much more difficult to know than the other animals; therefore their natural hiſtory is in general much leſs advanced.

In order to underſtand the methodical diviſion which we ſhall propoſe, from Artedi, Linnæus, and Gouan, it is requiſite to take a curſory view of their external anatomy. The bodies of fiſhes may be divided into three parts, viz. the head, the trunk, and the fins.

The head of theſe animals has different ſhapes. It is flattened either horizontally or laterally, or it is round; bare, or ſcaly; ſleek, or full of prickles, tubercles, &c. It is remarked, that their mouth is furniſhed with fleſhy or oſſeous lips, of appendices ſoft and very moveable; the teeth adhering to the jaws, the palate, the tongue, the gullet; the eyes, two in number, immoveable, without lids; two noſtrils on each ſide;

the opening of the gills, or the bronchiæ; the coverings, or the round, triangular, ſquare bones, deſigned to ſecure the opening of the bronchiæ; the bronchial membrane placed under the coverings, ſupported upon ſeveral props or bones in form of an arch, whoſe number varies from two to ten. This membrane is double under the coverings; and it is very important to examine its ſtructure and varieties, becauſe the characters of the genera are moſt frequently taken from the number or form of its fibres.

The trunk, like the head, differs in its form: it is either round, globular, long, flat, or angular. Its lateral line muſt be obſerved, which appears to divide each ſide of the body into two parts; the thorax, placed under the gills, at the beginning of the trunk, and filled by the heart and bronchiæ; the belly, whoſe ſides form the machinery, continued from the head to the tail, and which contains the ſtomach, inteſtines, liver, bladder, the parts of generation; the opening of the anus, which is common to the inteſtines, the bladder, and the parts of generation: laſtly, the tail, which ends the trunk, is of various form and extent.

The members or fins, pinnæ natatoriæ, are formed of membranes formed of ſmall fibres; ſome of which are hard, oſſeous, and terminated in a ſharp point, which conſtitutes the fiſhes called *acanthopterygious* by Artedi; others are flexible, ſoft, obtuſe, as if cartilaginous, which conſtitutes the fiſhes called *malacopterygious*. Five kinds of fins are diſtinguiſhed relatively to their ſituation; the dorſal, pectoral, abdominal, that of the anus, and that of the tail.

The dorſal fin is ſingle; it keeps the fiſh in equilibrium; it varies in ſituation, number, figure, proportion.

The thoracic fins are ſituated at the opening of the gills: they are two in number; they ſerve for arms, ſometimes even for wings: they differ in the place of their inſertion, their extent, their figure, &c.

The fins of the belly are the moſt important to be known, becauſe Linnæus has made uſe of their ſituation to determine diſtinctly the claſſes of fiſhes. Theſe fins are placed at the inferior part of the body before the anus, and always lower than the pectoral. They are ſometimes wanting; and as Linnæus has compared them to the feet, he has called thoſe fiſhes *apodes*, or *without the feet*, which want theſe kinds of fins. They are preſent, however, in the greateſt number of fiſhes; but their inſertion varies: when they are placed above or below the opening of the gills and the pectoral fins, they are called *jugular;* and likewiſe the fiſhes receive that name which have their fins inſerted in that place: if they are attached to the thorax, and behind the opening of the gills, then they are called *thoracic;* and likewiſe the fiſhes with this ſtructure have received the ſame name from Linnæus: Laſtly, when they are placed under the belly, nearer the anus than the pectoral fins, they are called *abdominal;* which name the fiſhes likewiſe get when they are thus formed.

The fin of the anus is ſingle. It occupies all or part of the region ſituated between the anus and tail; it differs in form, extent, number, although it never has been found double, except in the golden fiſh of China.

The fin of the tail is placed vertically at the extremity of the body, and terminates the tail: This is the helm of the fiſh, the inſtrument by which it changes, at its pleaſure, its direction according to its various motions. It exhibits alſo ſeveral varieties, in form, adherence or connection, extent, &c.

From theſe details upon the external anatomy of fiſhes, we paſs to the methodical diviſions of the naturaliſts. Before the time of Artedi, no naturaliſt had yet attempted a methodical diſpoſition of the fiſhes, although methods for claſſing the other animals had been offered. This philoſopher is the firſt who propoſed a ſyſtem of ichthyology, from the nature of the bones or the fins, hard or ſoft, prickly or obtuſe, or from the form of the gills. He next laboured to multiply the diviſions from other parts; but a premature death cut off his deſign. Linnæus thought of eſtabliſhing an ichthyological method, from the various ſituation of the fins of the belly: and M. Gouan, a celebrated profeſſor at Montpelier, combined with great ingenuity the ſyſtems of Artedi and Linnæus. This naturaliſt firſt divides the fiſhes into thoſe which have the gills complete, that is to ſay, formed of an opening and a bronchial membrane properly organiſed; and thoſe which have the gills incomplete, that is, which want either the bronchial membrane or the opening, or both. The firſt, then, are diſtinguiſhed by the form of their fins; in ſhort, theſe parts are formed either of hard and acute bones, or of ſoft fibres, as if cartilaginous. Theſe differences conſtitute three claſſes of fiſhes, viz. 1. the acanthopterygious; 2. the malacopterygious; 3. the branchioſtigious. In each of theſe claſſes of fiſhes, the abdominal fins being found either abſent, or placed at the neck, thorax, belly, M. Gouan has divided each claſs into four orders; that is, into apodes, jugular, thoracic, and abdominal.

As, from theſe firſt general diviſions, there are no more characters, to divide the genera into ſections and articles, as there are in the method of M. Briſſon for quadrupeds and birds, we ſhall have no need of reducing the method of Gouan into a table; and it will ſuffice to offer the genera under the claſſes and orders to which they belong.

Claſs. 1. ACANTHOPTERIGIOUS FISHES.

Order 1. *Apodes.*

Gen. 1. Trichiurus,
2. Xiphias,
3. Ophidium.

Order 2. *Jugular.*

Gen. 1. Trachnius,
2. Uranoſcopus,
3. Callyonimus,
4. Blennius.

Order 3. *Thoracic.*

Gen. 1. Gobius,
2. Cepola,
3. Coryphæna,
4. Scomber,
5. Labrus,
6. Sparus,
7. Chœtodon,
8. Sciœna,
9. Perca,
10. Scorpæna,
11. Mullus,
12. Trigla,
13. Cottus,
14. Zeus,
15. Trachipterus,
16. Gaſteroſteus.

Order 4. *Abdominal.*

Gen. 1. Silurus,
2. Mugil,
3. Polynemus,
4. Theutis,
5. Elops.

Claſs 2. MALACOPTERYGENEOUS FISHES.

Order 1. *Apodes.*

Gen. 1. Muræna,
2. Gymnotus,
3. Anarhichas.

Gen. 4. Stromateus,
5. Ammodytes.

Order 2. *Jugulares.*
Gen. 1. Lepidogaſter,
2. Gadus.

Order 3. *Thoracic.*
Gen. 1. Pleuronectes,
2. Echeneis,
3. Lepidopus.

Order 4. *Abdominal.*
Gen. 1. Loricaria,
2. Atherina,
3. Salmo,
4. Fiſtularia,
5. Eſox,
6. Argentina,
7. Clupea,
8. Exocætus,
9. Cyprinus,
10. Cobites,
11. Amia,
12. Mormyrus.

Claſs 3. BRANCHIOSTEGIOUS.

Order 1. *Apodes.*
Gen. 1. Syngnathus,
2. Baliſtes,
3. Oſtracion,
4. Tetraodon,
5. Diodon.

Order 2. *Jugulares.*
Gen. 1. Lophius.

Order 3. *Thoracic.*
Gen. 1. Cyclopterus.

Order 4. *Abdominal.*
Gen. 1. Centriſcus,
2. Pegaſus.

The characters of the genera are taken from the ſhape of the body, of the head, mouth, bronchial membrane, and particularly from the number of fibres which ſupport this membrane.

Claſs VI. INSECTS. ENTOMOLOGY.

INSECTS are animals which are known by the form of their bodies, as divided by rings, and by the preſence of two moveable horns which they have above the head, and which are called *antennæ.* Inſects compoſe one of the moſt numerous claſſes of animals, owing, undoubtedly, to their ſmallneſs; as it has been obſerved that the ſmaller theſe bodies are, the more their reproduction is multiplied. The hiſtory of theſe animals is one of the moſt agreeable, the moſt amuſing, and perhaps not the leaſt uſeful; as properties belonging to them may be found uſeful to medicine and the arts.

Inſects preſent in their claſſes an example of almoſt all the other animals, relatively to their manners, their form, their habitation.

Some walk like quadrupeds; others fly like birds; ſome ſwim and live in waters, like fiſhes; laſtly, ſome leap or crawl, like certain reptiles. This analogy may be puſhed even farther upon examing in detail the ſtructure of their extremities, of their mouth, their internal organs, &c.

Inſects, conſidered externally, are compoſed of three parts; head, breaſt, and belly.

The head differs in form, extent, and poſition. It is ſometimes very large, comparatively to the bulk of the inſect, and ſometimes very ſmall; it is either round, ſquare, long, ſleek, or rough, or full of tubercles, or covered with hair in certain places. It is obſerved, 1. The antennæ placed in the neighbourhood of the eyes, formed of different pieces, articulated and moveable, reſembling a thread, terminated in a point or by a maſs. The form of theſe organs is eſſential to be di-diſtinguiſhed, becauſe it is almoſt always the character uſed to diſtinguiſh the genera. 2. The eyes, which are of two kinds, in facets or a net-work, ſleek and ſmall: theſe organs are ſometimes very large, at other times very ſmall; their number varies. There are ſome inſects which have only one, as the monocolus; others two, as the ſpider. 3. The mouth, which is formed either of ſtrong horny jaws, placed and moved laterally, or of a trunk more or leſs long, dilated, ſpiral, &c. or only of one ſlit. This part is frequently adorned with ſmall moveable appendices, called *antennulæ*, two or four in number.

The breaſt of inſects: it is placed between the head and the belly; it is ſometimes round, ſometimes triangular, cylindrical, broad, narrow. It ſhould be conſidered as compoſed of ſix ſides, and likewiſe a kind of cube, whoſe form it aſſumes ſometimes. The face, or the anterior extremity, is hollowed to receive the head: this articulation is made ſometimes only by a thread, as in the fly. The occiput is generally round, and articulated with the firſt ring of the belly. Sometimes it is joined with this part only by a thread. The upper ſide is often flat and ſleek, ſometimes round, prominent, full of appendices, tubercles, terminated by a kind of projecting edge; which conſtitutes the thorax marginatus. It is to the hind part of this ſide to which the wings are attached. It is known that the greateſt part of inſects is provided with theſe organs, but they differ ſingularly from one another; and as it is upon theſe differences upon which are founded the principal diviſions of the claſſes adopted by the methodiſts, it is of importance to conſider them. Theſe wings are either in the number of two or four. Among thoſe which have two tranſparent ones, as the fly, midge, &c. theſe wings are always accompanied towards their inſertion and below it with a minute filament terminated by a round button, which is called *balter*, and which is covered with a concave membranous appendix called the *ſpoon.*

In a great number of inſects theſe two wings are very ſtrong, fold back, and are platted, under hard, horny, moveable caſes, called *elytra*. Theſe caſes differ in form: ſome cover all the belly; others are as if cut tranſverſely, and cover only a part of the belly; ſome are hard, others ſoft; moſt are accompanied to the height of the ſuture or line, by which they approach with a ſmall triangular piece ſoldered to the breaſt, which is called *ſcutellum*; this piece is wanting in ſome: laſtly, with inſects, in ſome caſes, the elytra are ſoldered, as if formed of a ſingle piece and immoveable.

The wings are often four in number; then they are either membranous and tranſparent, as in the beetles, waſps, &c. or they have upon each of their ſides a coloured powder, which with the microſcope preſents ſcales laid upon the wings like tiles upon a houſe, imbricatim.

The inferior part of the breaſt is irregular, formed of ſeveral pieces connected to one another, and in it is inſerted a part of the legs. The number of theſe laſt varies in inſects: many have ſix, others eight, as the ſpiders; in ſome there are ten, as in the crab: and ſome inſects have a much greater number. Sixty are to be counted in the wood-looſe; and ſome kinds of ſcolopendras have even ſeventy, and a hundred and twenty on each ſide. In thoſe which have only ſix, eight, or ten, they are all attached to the breaſt, according to Geoffroy: in thoſe which have a greater number, a part of the legs is inſerted in the rings of the belly.

The leg of an inſect is compoſed always of three parts; the thigh, leg, and tarſus. There is often beſides theſe an intermediate piece between the body and the thigh. The tarſus is formed of ſeveral pieces or rings articulated to one another: the number of theſe rings varies, and extends from two to five. There are even inſects whoſe tarſus of the fore feet is more conſiderable than the hind ones: which eſtabliſhes an analogy between the ſtructure of theſe ſmall animals and that of a great number of quadrupeds, whoſe fore-feet before have a greater number of toes than the poſterior feet. M. Geoffroy has taken part of this character for his diviſion; as we ſhall notice more afterwards. The tarſus is terminated by two, four, or ſix ſmall claws or hooks, and furniſhed below frequently with bruſhes or ſpongy balls, which ſupport and connect the inſect upon the moſt poliſhed bodies, as glaſſes, &c.

Upon each ſide of the breaſt one or two oblong oval openings are obſerved, which are called *ſtigmata*, and by which the inſect reſpires.

The third part of inſects is the belly. For the moſt part it is compoſed of rings, or of horny half rings, which are inchaſed into one another. Sometimes no rings at all are obſerved, and the belly appears formed only of one ſingle piece. It is generally larger in females than in males. It has the parts of generation fixed to its extremity. In its ſides a ſtigma is obſerved upon each ring, except upon the two laſt. At the poſterior part of the belly ſeveral inſects carry their ſtings; ſome of which are very acute and ſharp, others ſerrated, and others like a wimble. They ſerve either as inſtruments of defence, or to pierce the places where the inſect is to depoſite its eggs.

The moſt ſingular phenomenon in inſects, and that in which they differ entirely from moſt of the other animals, is the changes of ſtate through which they paſs, or the metamorphoſes which they undergo before they become perfect inſects. There are ſome inſects, and almoſt all thoſe of the apteræ, which ſuffer no ſuch changes; but the greateſt number are ſubmitted to them. No inſect comes out of its egg with the mother's form; but it appears in the form of a worm, with or without legs, and whoſe ſtructure of the head and wings greatly varies. This firſt ſtate is called *larva:* under this kind of maſk the inſect eats, turns larger, moves, and changes its ſkin ſeveral times. When it has come to its full growth, it changes ſkin for the laſt time, but it is no longer in the form of a worm or larva, but in quite a different one, called *nympha*, *chryſalis*, *aurelia.*

M. Geoffroy diſtinguiſhes four kinds of nymphæ. The firſt is that which does not reſemble an animal; ſome rings are obſerved only on the under part, and the upper preſents only indiſtinct impreſſions of antennæ, legs, and wings. The ſkin of this kind is hard, cartilaginous, and it has only a few motions in its rings, as in the butterfly, &c.

The ſecond kind of chryſalis diſcovers the parts of the perfect animal inveloped in a very minute and ſoft ſkin. It is immoveable like the firſt. Inſects in caſes, thoſe with four bare wings, and thoſe with two, furniſh examples. The third kind is that whoſe wings are fully evolved and apparent, and which move. Such are the midges, and the inſects which paſs the two firſt ſtates of their life in water.

Laſtly, the fourth kind comprehends thoſe which reſemble the perfect inſect, in the form of the body, the preſence of the antennæ, and paws. Theſe nymphæ move and eat. They differ from perfect inſects only in the abſence of the wings, and in their being unfit for generation. The nymphæ of the beetles, bugs, locuſts, &c. are of this kind.

The hiſtory of inſects laboured under the ſame difficulties as that of other animals. The ancient naturaliſts had diſtinguiſhed them only by the places which they inhabit. Before Linnæus no perſon had undertaken to diſpoſe them methodically, and to offer characters by which they might be diſtinguiſhed. This naturaliſt has the merit of the firſt ſyſtematic diviſion of theſe animals. Geoffroy afterwards undertook to claſs them in a more exact manner. His diviſion of ſections and genera is a maſter-piece of accuracy, preciſion, and perſpecuity. We ſhall adopt his diviſion.

Geoffroy divided the inſects into ſix genera, from the abſence, ſtructure, and number of the wings. The firſt ſection comprehends the coleopteræ, or inſects whoſe wings are covered with a caſe. Their mouth, of two lateral horny jaws, alſo forms a ſecond general character of this ſection. The May-bug preſents theſe two characters.

The ſecond ſection comprehends the hemipteræ; the upper parts of whoſe wings are either ſomewhat thick and coloured, or half hard and opaque: but the character of the wings, which is not exact in this ſection, is replaced by that of the mouth, which is conſtant. This mouth is a long acute trunk, folded back below between the paws. The wood-bug and cicada belong to this ſection.

The third ſection is compoſed of *tetrapteræ* with farinaceous wings, whoſe four wings are coloured by a ſcaly powder, and which have a trunk more or leſs long, frequently twiſted ſpiral-ways, as the butterfly. Linnæus calls theſe *lepidopteræ*.

In the fourth ſection, the *tetrapteræ* are comprehended, with bare wings. Their four wings are membranous; they have hard jaws: of this ſort is the waſp. Linnæus made two orders of theſe inſects: the *neuropteræ*, whoſe anus has no ſting, and whoſe wings are marked with nerves; and the *hymenopteræ*, which have the anus armed with a ſting, and the membranous wings without any very apparent nerves.

The fifth ſection contains the *dipteræ*, or thoſe with two wings; their mouth is moſt frequently formed of a trunk, and they have balancers and ſpoons under the origin of their wings.

In the ſixth and laſt ſection, the *apteræ*, or thoſe without wings, are ranked; as the ſpider, louſe.

Be-

Beſides theſe firſt diviſions, Geoffroy has eſtabliſhed others to facilitate the diſtinction of inſects.

LECTURE LX.

Claſs VII. VERMES.

WORMS are ſoft animals, of a very different form from that of the inſects, with which they have been confounded by ſeveral naturaliſts. They have no bones, properly ſo called; and their members are not conformed as thoſe of inſects; they are not obliged like them to paſs through different ſtates. It is the want of feet, properly formed like thoſe of inſects, and the conſtant and immutable form, which they keep all their life, which make their proper characters, and which diſtinguiſh them from other animals.

The claſs of worms is the moſt numerous and leaſt known of all animals. There are few dead or organiſed ſubſtances in which ſome worms are not found, which find their nouriſhment there. The moſt part of naturaliſts, and Linnæus himſelf, have put in the ſame claſs the vermes and polypi; but their internal ſtructure and functions are entirely diſtinguiſhed. A heart and veſſels are found in moſt worms; and nothing ſimilar is found in the polypi.

We muſt fully diſtinguiſh the worms of which we are now treating, from the animals which are only larvæ of inſects, and which have for that reaſon received the name of *worms* on account of their form. Their head, furniſhed with a jaw, and the legs, which they have more or leſs, moſt commonly ſix, afford characters by which they may be eaſily diſtinguiſhed.

The worms have a great deal of motion: they love and ſeek for humidity: ſome have no very diſtinct head: the moſt part are hermaphrodite. Thoſe which have a head have it armed with two moveable retractible horns, called *tentacula*. It ſeems, that almoſt all the worms, of which we ſhall give an abridged account, have the property of being reproduced when they are cut through; which indicates a ſimple organiſation, and that their nature approximates to that of the polypi.

The worms may be divided into three ſections. The firſt ſhall contain the bare worms, whoſe organiſation is beſt known, and which approximate in this character to the other animals. In the ſecond, we ſhall rank the worms inveloped in a teſtaceous covering, or the ſhell-worms: their organs are leſs known than thoſe of the firſt: however, the excellent reſearches of M. Adanſon prove, that their ſtructure approximates to the bare worms. The third ſection will comprehend the worms with a cruſtaceous covering: their organiſation is not ſo well known as that of the preceding, and their external form and ſtructure of the mouth alone has as yet been examined.

SECT. I. *Vermes Nudi.*

It is eaſy to figure the difference which exiſts between the worms compriſed in this ſection and thoſe of the two others: they are bare, and without any calcareous or cruſtaceous covering. There are ſix different genera in this ſection.

Genus 1. *Gordius.*

This worm, according to Linnæus, has a body like a round wire, the mouth forked, the jaws horizontal and obtuſe: its body is pale, and its two extremities are black. Geſner and Aldrovande have called it *vitulus aquaticus*. The vena medinenſis belongs to this genus.

Genus 2. *Lumbricus.*

This worm's body is formed of rings: its anterior extremity is pointed; its genital parts are at the neck; it is hermaphrodite and oviparous. The earth-worm, that of the inteſtines of men, and the ſea-worm, are the three kinds well known.

Genus

Genus 3. *Aſcaris.*

Its body is ſleek, and its extremities are acute: it is to be ſometimes found in the rectum of children.

Genus 4. *Hirudo.*

Its body appears to be ſwelled in the middle: its extremities dilate into a roundiſh and flat body: its head is armed with three ſmall tuberoſities, which make a wound with three angles upon an animal's ſkin, to which it adheres. Its mouth is the pump, and a ſort of fleſhy tuberoſity, placed at the bottom of this cavity, is the piſton. Such is the mechaniſm by which the leech ſucks the blood.

Genus 5. *Limax.*

Its body is oblong, covered with a ſhield or fleſhy mantle above, and formed of a muſcular ſheath below. There are ſeveral kinds of ſnails, which differ in ſize, colour, ſhades.

Genus 6. *Tænia ſolium*, *Vermis ſolitaris.*

It has received this name, becauſe it has been ſuppoſed to be found alone in the inteſtines of animals: but it is an error; ſeveral have been found in man. There are ſometimes dozens in horſes, dogs, fiſhes, &c. The character of this animal is of being flat like a riband, and formed of diſtinct articulated rings, having a fine elongated extremity, which has been ſuppoſed its head. It is thought that each ring is a particular animal, which lives and is nouriſhed ſeparately. It is of a very conſiderable length, frequently ſeveral yards long. It is reproduced when it is cut; ſo that animals are not cured unleſs it be taken out entire. It lives in the inteſtines of almoſt all animals. The different kinds of tænia have not yet been well examined. Two are diſtinguiſhed in man; the one with ſhort rings, the other with long. The nature of this worm is not yet properly known, notwithſtanding the labours of Meſſrs Andry, Tyſon, Herrenſchvands, Bonnet, Butini. It ſeems to approach much to the polypi. Linnæus has deſcribed a round kind of them articulated, of a ſhining white, ſaid to be found in marſhes. He ſpeaks alſo of a flat white worm, which he calls *faſciola*, very different from the tænia, in its not having articulations. A very ſmall kind is found near rivulets, and likewiſe in the liver of ſheep; there is another much longer, and is found in the inteſtines of fiſhes.

SECT. II. *Vermes Teſtacei.*

THESE are covered with a ſhell of the nature of chalk. Moſt naturaliſts have paid attention only to this covering, and have founded methods upon the form of the ſhells. M. Adanſon is one of the firſt who has undertaken to deſcribe the inhabitants of the ſhells, and to diſtinguiſh theſe animals from their internal form. This work is very little advanced and very difficult. We ſhall point out the road of the naturaliſts in the diſtribution of the ſhells. M. Dargenville is the author who has given the moſt clear and moſt complete method. He divides the ſhells into three orders. The firſt comprehends the ſhells of a ſingle piece, *univalvæ, cochleæ;* the ſecond, the ſhells of two equal and ſymmetrical pieces, *bivalvæ, conchæ;* the third, the *multivalvæ* or *polyvalvæ*, which are formed of more than two pieces united.

Order 1. *Univalvæ, Cochleæ.*

Familiæ ſive genera 1. Patella,
2. Haliotis,
3. Tubulus, dentalium,
4. Nautilus,
5. Cochlea,
6. Nerites,
7. Trochus,
8. Cylindrus,

Familiæ ſive genera 9. Voluta,
10. Strombris,
11. Buccinum,
12. Murex,
13. Purpura,
14. Porcellana,
15. Globus.

Order 2. *Bivalvæ, Conchæ.*

Familiæ ſive genera 1. Oſtrea,
2. Chama,
3. Concha cordis,
4. Pecten,
5. Mytulus,
6. Solen.

Order 3. *Multivalvæ vel polyvalvæ.*

Familiæ ſive genera 1. Pholas,
2. Balanus,
3. Concha anatifera.

SECT. III. *Vermes Cruſtacei.*

THIS ſection is the leaſt numerous and leaſt known ; comprehends two genera well characteriſed.

Genus 1. *Aſterias.*

ITS mouth is in the middle of the body; its cruſtaceous covering is divided into filaments, which have the form of a net-work.

Genus 2. *Echinus.*

ITS mouth is at the baſe of a cruſtaceous round and vaulted covering, ſet full of prickles. M. Dargenville has placed the urchins in the order of the multivalvæ; M. Klein has made a complete work upon theſe animals, intitled, *Naturalis diſpoſitio echinodermatum.* The ſituation of the anus appeared to him ſuſceptible of furniſhing a proper method for diſtinguiſhing them. He has divided them into three claſſes. The firſt comprehends the anocyſti, whoſe anus is placed at the top or higheſt place of the vault: the ſecond contains the catocyſti, which have the anus placed below. In the third claſs, he places the pleurocyſti, whoſe anus opens neither at top nor bottom, but at the ſurface or the ſide.

The characters of the ſections and genera are taken from the form of the arch, and from their points or adpendices.

Claſs VIII. Polypi.

The polypi conſtitute the laſt claſs of animals. They are the leaſt perfect, and ſome of them ſo reſemble vegetables, that naturaliſts have for a long time compriſed them in the number of theſe laſt.

The ancients gave the name of *polypi* to animals more or leſs voluminous, having a great number of feet, and which are uſed as a delicate diſh.

By this name we underſtand all moving animals, whoſe organiſation ſeems ſimple, which are not known to have a heart, and which are formed only of a membrane, turned round into ſacs, furniſhed with a great number of feet or horns. The polypi have alſo a property which diſtinguiſhes them, which is, they have the power of contracting and entirely loſing their form. They live for the moſt part, united in a conſiderable number, in the ſame habitation. They are reproduced by kinds of grains which are ſeparated from their ſurface, and adhere to bodies; or they grow like vegetables. If they are cut, they ſhoot and are renewed like a ſlip of a tree. We divide them into four ſections.

Sect. I. *Polypi Nudi.*

These polypi are not covered with any hard ſubſtance or caſe: they fix to rocks or any ſolid body. Two genera are diſtinguiſhed.

Genus

Genus 1. *Polypi aquæ dulcis; Hydra Linnæi.*

M. Trembly has deſcribed theſe ſmall animals with great accuracy. They are formed of a body or long tube, at the extremity of which is a dilitation, which is the mouth. The ſide of this cavity is ſurrounded with a great number of filaments, or contractile moveable horns, which ſerve the animal for catching and devouring its prey. This author has diſtinguiſhed ſeveral kinds from their ſize, colour, form: Such is the polypus with arms, polypus of the colours of the peacock, &c.

Genus 2. *Sea-Nettle.*

It repreſents a truncated conical body, flabby, contractile, whoſe mouth is armed with horns or feet. Linnæus, and moſt part of the naturaliſts, have ranked them among the zoophytes, or animals which reſemble plants *.

Sect. II. *Polypi in cellulis corneis, ſive quaſi ligneis.*

The character of the polypi of this ſection is, they adhere to the branches of ſubſtances, either horny, or flexible and fibrous, as young twigs of trees and plants. Theſe ſubſtances were compriſed alſo among vegetables, down to Peyſonel, Ellis, Donati; who have proved that they really belong to animals. They have been called *zoophytes* on account of their form, and *lythophytes* on account of their hardneſs.

Genus 1. *Keratophytes*, or *Lithophytes*, *properly ſo called.*

It is a polypus frequently elaſtic, formed by a matter of different colours, which cuts and fuſes like horn, poliſhes like it, and burns with its ſmell. Black and articulated coral are of this ſort.

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* It has been uſual to rank the cuttle-fiſh here; but their more perfect organiſation, the preſence of a heart and a ventricle, obſerved and deſcribed by Swammerdam, make them approach the fiſhes. M. le Cat calls the cuttle fiſh a fiſh-inſect. It is a ſubſtance, indeed, which ſeems to hold the middle-rank, and to ſerve as a paſſage between theſe two claſſes of animals.

Genus 2. *Sertularia ſive corallina.*

Nothing more reſembles plants than this production of polypi. M. Ellis has given a deſcription of a great number of kinds of this ſubſtance. He diſtinguiſhes them into four families; to wit, the veſicular, the tubular, the cellular, and articulated. The two laſt families ſeem to be not of the ſame horny nature as the two firſt.

Sect. III. *Polypi in Cellulis Cretaceis.*

This kind of polypi conſtructs and inhabits ſolid ramifications of a various form, but they are all of the nature of chalk. They are in general more voluminous than the former, and particularly the corallina. The genera which compoſe this ſection are diſtinguiſhed, like thoſe of the preceding, by their habitation; the animals which build them reſemble, for the moſt part, thoſe of the preceding, viz. they are ſmall contractile ſacs, furniſhed with a greater or leſs number of feet at their extremity, and which differ in ſize, colour, form, &c.

Genus 1. *Corallium.*

The coral is a habitation of polypi, hard and calcareous, which has the form of a plant. This habitation is formed of layers; it is ſolid only in the middle; it is covered with a kind of bark, pierced with a great number of holes, in which the polypi are implanted. Three or four kinds of coral are diſtinguiſhed in the ſhops; the red, the roſe, the white, &c.

Genus 2. *Madrepora.*

The madrepore differs from the coral in its having a more tender texture and more ſtony aſpect. Beſides, its ſurface is pierced with a great number of holes, which penetrate into the heart of the calcareous ſubſtance, whilſt theſe holes are found only upon the bark of the coral, and the bark is wanting in madrepores. The ramified form, like vegetation, or in maſſes ſimilar to muſhroms, a cap, a hand, has given different names to madrepores. The beſt method of diſtinguiſhing them, conſiſts, in general, in the characters taken from the form of the holes. Dr Pallas, in a very good work upon the zoophytes, intitled, *Elenchus Zoophytorum*, has given the beſt diviſions of marine animal productions whoſe form imitates that of vegetables.

SECT IV. *Polypi in cellulis mollibus et ſpongioſis.*

IT is eaſy to diſtinguiſh the polypi of this fourth ſection from thoſe of the two preceding, by the ſoft, flexible, and cellular nature of their habitations. We are acquainted with three kinds of habitations which ſeem to belong to this ſection.

Genus 1. *Eſcarra.*

THIS matter is known by its ſofter, ſometimes friable, frequently pliant nature, and by its being formed of very fine celullæ, which imitate the holes and the texture of a wide wrought web: in theſe cells the polypi lodge.

Genus 2. *Spongia.*

THE texture of the ſpongia is as if parenchymatous, A great number of kinds has been diſtinguiſhed by the form of the holes, the texture. Their figure has made them get different names, as Pan's flute, wax-candle, Neptune's cup, ſea agaric, &c. All the cells of the ſpongia communicate, and they ſerve as the habitation of a great number of polypi.

Genus 3. *Alcyonium.*

THE name of *alcyonium* is given to the ſpongy, fleſhy, or gelatinous bodies, irregularly rounded, which lodge the polypi in their ſubſtance. This ſingular marine production has not yet been rightly examined: it has got names relatively to its form only; ſuch as the ſea-beet, ſea-waſp. They ſeem to be the laſt link of the chain of animals.

LECTURES LXI. LXII.

Of the FUNCTIONS *of* ANIMALS, *conſidered from Man down to the Polypi.*

THE characters peculiar to living and organic bodies are, as has been ſeveral times obſerved, the different functions performed by their different organs. We have conſidered them in vegetables: the order which we have adopted likewiſe requires that we conſider them in animals.

The part of medicine which treats of the functions of animals is Phyſiology. This excellent ſcience ought not to be limited to man alone: it ſhould be extended to all animals: and under this point of view we ſhall curſorily conſider it.

The functions of animals may be reduced to the following:

1. Circulation; 2. Secretion; 3. Reſpiration; 4. Digeſtion; 5. Nutrition; 6. Generation; 7. Irritability; 8. Senſibility. Theſe different functions are found in man, quadrupeds, cetacea, birds, fiſhes, reptiles, inſects: the worms and polypi poſſeſs none of theſe at all, and the claſſes before theſe two laſt do not poſſeſs them in the ſame degree.

1. Circulation is one of the firſt functions; it is the ſupport of life: when it ceaſes, the animal inſtantly dies: the organs which preſide over it are, the heart, arteries, and veins.

The heart is a conical muſcle which has at its bottom two cavities, called *ventricles*. At its baſe are two other ſacs, called *auricles*. From the left ventricle a very large artery goes out, called *aorta*, which diſtributes the blood to all the body: from the right ventricle another artery alſo goes out of an equal ſize, called *pulmonary artery*, becauſe it is ramified in the lungs. The right auricle receives the blood in its return from the whole body by the two venæ cavæ: this fluid paſſes into the right auricle, from thence into the right ventricle; from this laſt it is poured into the lungs through the pulmonary artery, and it returns by the pulmonary veins into the left auricle; from thence it paſſes into the left ventricle, which ſends it through the whole body by the aorta. This motion, thus going on in man, conſtitutes two kinds of circulation, that through all the body, and that through the lungs: this laſt was known before the other; the general circulation was diſcovered by the celebrated Dr Harvey an Engliſh phyſician.

Among the quadrupeds, the cetacea, and birds, this function is the ſame way performed as in the man. Among the fiſhes the heart has only one ventricle, and the lungs or gills receive no blood by a particular cavity from the heart. In reptiles it is performed as in fiſhes. Inſects and worms have a heart formed of a ſet of knots, which contract one after the other; their veſſels are very ſmall; their blood is cold and colourleſs. The polypi have neither heart nor veſſels; they are leſs perfect than vegetables with reſpect to this kind of function.

2. Secretion is a function by which juices are ſeparated from the blood in the different organs deſtined for particular uſes, as the bile in the liver, &c. This function is one of the moſt extenſive in all animals: it is found in all animals; but it is impoſſible to deſcribe it, without entering into very extenſive details. It ſhall therefore ſuffice to obſerve, that in all animals in which there is a true circulation, the ſecretion follows the ſame laws as in man; and it alſo appears to be performed in the moſt part of animals which have no heart. Beſides the

analogy which ſubſiſts neceſſarily between man and the animals which poſſeſs the ſame organs with him relatively to this function, each claſs of animals preſents particular ſecretions which are not found in man; ſuch as muſk and civet in quadrupeds; ſpermaceti in the cetacea; the oily juice deſtined to cover the feathers of birds; the poiſonous humour of the viper; the gluey fluid of the ſcales of fiſhes; the acrid juices of ants and waſps; the viſcous mucilage of ſnails; the colouring juices of purſlain, and a great number of others which the natural hiſtory of each animal makes known.

3. Reſpiration, conſidered in all animals, is a function deſtined to put the blood into contact with the fluid which they inhabit: man and quadrupeds have for this purpoſe an organ, called *lungs*. This viſcus is a maſs of hollow veſicles, which are only expanſions of a membranous and cartilaginous canal, called *trachea arteria;* and of blood-veſſels, which ſpread out, forming a great number of little holes at the ſurface of the bronchial veſicles. Theſe veſicles and veſſels are ſupported by a cellular texture, looſe and ſpongy, which forms the parenchyma of the lungs. The air diſtends theſe veſicles in reſpiration: the pure and vital portion of this fluid is abſorbed by the blood, which it renews, and to which it gives colour and concreſcibility. The air which is thrown out by reſpiration is impure; it troubles lime-water; it reddens the tincture of tournſol; extinguiſhes candles, and can no longer ſerve another reſpiration.

Among the cetacea this function is likewiſe performed; only as there is an immediate communication between the auricles, theſe animals can remain ſome time without reſpiring.

Though the reſpiration of birds be analogous to that of the preceding animals, this function ſeems to be much more extenſive in them. Indeed, anatomiſts have diſcovered in the belly of birds ſpongy veſicular organs which communicate with their lungs, and theſe laſt open juſt into the bones of the wings, which are hollow and without marrow, by a canal placed above the breaſt, which opens into the upper part and ſwell of the os humeri. This pretty diſcovery, made by M. Camper, ſhows us, that the air paſſes from the lungs of birds into the bones of the wings; and that this fluid, rarefied by the heat of their bodies, renders them very light, and ſingularly promotes their flight.

Fiſhes have gills or bronchiæ inſtead of lungs: theſe organs are formed of membranous fringes, placed upon a bony arch, and full of blood-veſſels. The water enters by the mouth of the fiſhes; it paſſes acroſs the fringes, which ſeparate from one another; it ſqueezes and agitates the blood; and it goes out again by openings placed at the lateral and poſterior parts of the head, upon which two mvoeable bony pumps are placed, called *lids*, and ſupported by the bronchial membrane. Duverney thought that the bronchiæ ſeparated the air contained in the water. M. Vicq d'Azir, who ſo ſucceſsfully ſtudied comparative anatomy, and in particular that of fiſhes, ſuppoſes that the water does the office of air in the bronchiæ of theſe animals.

Inſects and worms have no lungs: they have canals or tracheæ placed all along the back; upon which, on each ſide, other ſmaller canals border, which terminate at the lateral part of each ring by a ſmall fibre called *ſtigma.* The ſtigmata are deſigned for reſpiring the air and expiring it. When they are covered with oil, the inſect ſuffers greatly: it turns convulſed, and dies. Worms have a ſtill more perfect organiſation. No kind of reſpiration is ſenſible in the polypi, which are leſs perfect in this function than vegetables, in which we have found tracheæ.

4. Digeſtion is the ſeparation of the nouriſhing matter contained in the aliments; and its abſorption by particular veſſels called *chyliferous;* it goes on in a canal continued from the mouth to the anus, and this canal is ſwelled out near about the top of the abdomen. This ſwelling is called the *ſtomach.* The alimentary ca-

canal then follows: it is twiſted to different ſides, and is called *inteſtines*. This long tube, which is formed of muſcles and membranes, is deſigned to retard the aliments, ſo as to extract all the nouriſhing ſubſtance which they contain. There are, beſides, in the neighbourhood of the ſtomach, other glandular organs, whoſe office is to prepare fluids proper for ſtimulating the ſtomach and inteſtines, and for extracting the nouriſhing part of the food; theſe are, the liver, the ſpleen, and the pancreas: the bile and pancreatic juice flow into the firſt inteſtine, called *duodenum*, and are mixed with the aliments, to which they communicate an animal character, which aſſimilates them to the humours.

All the paſſage of the firſt inteſtines is filled with vaſcular mouths, deſtined to forward the chyle. Theſe veſſels carry it into the lumbar reſervoir, into the thoracic canal, and the chyliform fluid is carried into the left ſubclavian vein, in which it mixes with the blood. Such are, in few words, the mechaniſm and phenomena of digeſtion in man.

Quadrupeds differ greatly in the form of their teeth, ſtomach, and inteſtines. There are ſome of theſe animals which have no teeth at all; as the ant, which eats only ſoft aliments: others have only dentes molares, as the tatou: ſome, as the elephant and ſea-cow, have molares and canini: laſtly, moſt of them have three kinds of teeth, molares, canini, and inciſivi; but their number, poſition, and ſtrength, vary prodigiouſly. What is moſt aſtoniſhing in this different ſtructure of the teeth is, that there is a conſtant relation between the number and poſition of the teeth and the form of the ſtomach, according to the remark of Ariſtotle and Galen. Indeed, all quadrupeds which have dentes inciſivi in both jaws, as the horſe, the ape, the ſquirrel, the dog, the cat, have only a membranous ventricle, like man. Anatomiſts call theſe animals *monogaſtrici*; digeſtion is performed entirely in the ſame manner in them as in man. The quadrupeds which have dentes inciſivi only

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in the lower jaw are the polygaſtric and ruminant; the camel, camel-opardalis, ram, goat, ox, ſtag, and kid. Theſe quadrupeds are generally *biſulci*, and armed with horns. They all have four ſtomachs. The firſt is called, in the ox, the *paunch*, the receiver of the herbs: it is the greateſt, and divided into four other ſacs: it receives the aliment at the ſame time with the ſecond, which opens into the paunch by a large orifice: the herbaceous aliments contained in theſe organs dilate, the air is rarefied in them: they ſtimulate the nerves of theſe viſcera, and produce an antiperiſtaltic motion, which drives them up into the œſophagus and mouth, where they are again chewed by the dentes molares: reduced into a kind of ſoft paſte by this operation, they are, as a fluid, carried, by a new deglutition, into the third ſtomach, the manyplies, the omaſus, by means of a half-hollowed canal from the œſophagus to this ventricle: laſtly, they ſoon paſs from hence into the fourth ſtomach, where they undergo true digeſtion. The inteſtines of ruminating animals are alſo far more extenſive than thoſe of monogaſtric quadrupeds. The cetacea reſemble entirely theſe laſt in the mechaniſm of this function *.

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* The muſcular ſtructure of the œſophagus of herbivorous animals is very evident, which we find to terminate juſt where two ſacs or ſtomachs unite, the largeſt of which is on the left ſide: it has a very curious ſtructure; we diſcover in it a number of round papillæ, which increaſe the ſurface of it greatly. We call it the *venter*, *ventriculus*, or *ingluvies*, which may be compared to the croop of birds. The ſecond ſtomach has ſtill a more curious ſtructure, reſembling very much a ſection of a honeycomb, which is perhaps a very good name for it. This leads us to the third ſtomach; in which we find a number of beautiful proceſſes, and on every one of them a number of papillæ; or we find a number of plicæ, and hence the beſt name *manyplies*. Now, the laſt ſtomach reſembles our own much more nearly than any of the reſt does; it has a number of valvulæ conniventes, diſpoſed longitudinally, and which are more remarkable here than in man: then this ends in the pylorus.

Every perſon may recollect what probably they may have ſeen, that a cow or ſheep, after feeding a certain time, commonly lies down, and appears ſtill to be eating or chewing; and a ball is obſerved

The birds differ from one another in the ſtructure o their ſtomach; ſome are membranous, others fleſhy o muſcular. The firſt, called *hymenogaſtric*, are carnivorous. The ſecond, which deſerves the name of *myogaſtric*, live only on grains: their ſtomach is formed o

ſerved to aſcend and to deſcend alternately in the throat. The creature makes an effort; the ball riſes; then chewing a certain time, it ſwallows the ball; and the motion is ſo rapid, that the eye ſcarcely follows the ball.

The animal then takes in a ſufficient proviſion, receives it into the firſt ſtomach, which, after having lain there a certain time, it is brought from thence up into the mouth; we muſt ſuppoſe it returns, not into the ſame, but into the ſecond ſtomach, from the ſecond into the third, and from this into the fourth. When drink is taken, we do not obſerve that the animal receives the drink into the firſt ſtomach, brings it up to the mouth, and ſo back again; but taking a large quantity, it fills the firſt ſtomach, and makes it paſs by degrees into the reſt; and a calf does the ſame with milk. Nay, it may run directly from the œſophagus along the guttter into the fourth ſtomach.

Now we ſee at once the intention of nature in beſtowing ſo many ſtomachs; it is to enable the animal to convert the moſt groſs parts of vegetables into aliment, that nothing may be loſt. The dung of a horſe, which does not ruminate, is a much richer manure than the dung of a cow, from which the nutritious part is more thoroughly extracted. But we apply this farther in phyſiology. We have the cleareſt proof of a living principle, ſuperior to reaſon and experience, operating upon the active parts of animals. We ſee the ſtomach acting in various ways, according to the utility, without the animal knowing more of its inward make than we do. It is evident that every ſtomach poſſeſſes a different organiſation; and the concluſion to be hence inferred is, that the liquors from the mouth and ſtomach ought not to be conceived as ſerving merely for dilution, but that they act as menſtrua; for if a greater extent of ſurface alone was neceſſary, the ſame ſtructure would ſerve in all; but in every ſtomach a certain operation is performed by its liquor, as a menſtruum. Pieces of bones ſwallowed by animals are digeſted, and ſcarcely any veſtige of them is to be afterwards found: hence we may imagine, that the action of the ſtomach is much more complex than it has hitherto been ſuppoſed.

We obſerve, that the alimentary canal of the herbivorous animal is much longer than that of the carnivorous; ſo further changes need to be made, to render the food like to the conſtitution of the animal, and ſafe to be received; and the changes happening in the laſt a quadrigaſtric muſcle, inveſted with a hard and thick membrane proper for trituration. Theſe birds alſo have a double cæcum.

Fiſhes have a membranous ſtomach, long, furniſhed with ſeveral appendices: their inteſtines are in general ſhort. We find a liver, but no pancreas. Reptiles preſent the ſame ſtructure: their ſtomach is diſtended in a wonderful manner. Serpents are obſerved to ſwallow animals which are often larger than themſelves.

Inſects have a ſtomach and inteſtines fully organiſed. Swammerdam and Perrault ſay, that the mole has four ſtomachs: it is a ſtomach ſwelled and divided into four ſacks, as we may be convinced by diſſection. Worms have a very irregular ſtomach; ſmall inteſtines are alſo found. The polypus ſeems to be only a ſtomach, for it digeſts very quickly: the ſame opening ſerves for a mouth and an anus

5. Nutrition is a continuation of digeſtion and circulation: the ſolids always loſing by the motion which they perform, muſt be repaired; and they are ſo by nutrition.

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laſt part of the canal are neceſſary for the crude nature of the aliment in the upper end; and we are yet far from knowing the power of the inteſtinum cæcum. In the human body, it may be conſidered as an organ, chiefly for preparing a ſlimy matter; but in many animals, eſpecially thoſe living ſolely upon herbs, we find it of a very great ſize, nearly equal to the diameter of the ſtomach itſelf: in the bat, it is to the feel larger than the ſtomach; ſo a very great deal, in every part of digeſtion, ſtill remains to be diſcovered by experiment.

The nouriſhment is abſorbed here as in man, and conducted through the lacteals into the meſenteric glands: and the only circumſtance here is, that the ſeveral glands are collected near the root of the meſentery, which is more tranſparent than in us, the fat following the courſe of the principal veſſels.

After the lacteals have paſſed through theſe glands, they proceed in the uſual manner upwards, till the nouriſhment gets into the circulating maſs; though, after it gets there, we can ſtill ſee it floating upon the ſurface of the blood for ſome time: ſo that authors who have ſuppoſed that the lungs and other organs contribute much to the mixture of the chyle with the blood, though proceeding on conjecture, have really propoſed true opinions.

trition. In the firſt age of life, they acquire ſize, and the animal grows larger. Generally the cellular texture is conſidered as the organ of this function, and the lymph as the humour adapted to repair the ſolids. However, it appears, that each organ is nouriſhed with a proper and particular matter, which it ſeparates, either from the blood, the lymph, or any other fluid which moiſtens it. For example, the muſcles are nouriſhed from the fibrous matter which they ſeparate from the blood: the bones extract a calcareous phoſphoric ſalt and a lymphatic matter: the pure lymph is dried into plates in the cellular texture; the concreſcible oil is depoſited in theſe plates, to give riſe to the fat: each viſcus, then, has its particular manner of being nouriſhed, and the nutrition of each of them is a true ſecretion. Quadrupeds and the cetacea reſemble man perfectly in this function: the ſame thing happens alſo among birds: in fiſhes it is performed leſs quickly; on that account theſe animals live a very long time, and even the age of ſome is not known; in general, the ſlower the nutrition and growth, the longer the life.

Inſects have nothing particular in this function; only they grow ſolely under the form of larvæ, and not in the form of chryſalides and perfect inſects. Swammerdam and Malpighi have demonſtrated, that the larva contains, under ſeveral ſkins, the perfect inſect ready formed: the caterpillar alſo contains the butterfly, whoſe wings and feet are folded back.

In the worms and polypi, nutrition is performed in the cellular texture; it is done alſo in the ſame way in vegetables, by means of the reticular and veſicular textures.

6. Generation, conſidered in all animals, is performed in many different ways: the moſt require coition, and poſſeſs two diſtinct ſexes; ſuch are man, quadrupeds, and cetacea.

Female quadrupeds have a matrix, ſeparated into two cavities, *uterus bicornis*, and dugs in a greater number:

they are not ſubjected to the menſtrual flux; the moſt of them bring forth ſeveral at a birth; their geſtation continues a ſhorter time: ſeveral have a particular membrane, deſtined to receive the urine of the fœtus; this membrane is called the *alantoides*.

The generation of birds is very different: the males have a very ſmall genital organ without a cavity; it is often double. Among the females, the vagina is placed behind the anus: theſe are ovaria without matrices, and a canal, deſtined to convey the egg from the ovarium into the inteſtine; this is called *oviductus*. The egg of the chicken, fecundated and not fecundated, has preſented facts unattended to by phyſiologiſts who have examined the phenomena of incubation. Malpighi and Haller are the only perſons who have made important diſcoveries. The laſt found the chick ready formed in eggs not fecundated.

Among fiſhes there is no decided proof of coition: the female depoſites its eggs upon the ſand; the male paſſes over them, and ejects upon them his ſeminal liquor, undoubtedly requiſite to fecundate them. Theſe eggs then hatch in a certain time.

The moſt part of male reptiles have a double or forked organ: theſe animals are oviparous, except the viper.

Inſects themſelves alone preſent all the varieties to be found among other animals. Some have two ſeparate ſexes in two ſeparate individuals; it is even the greateſt number. Others produce with or without coition, as in the vine-fretter: one of theſe inſects, contained alone under a glaſs, produces a great number of others. M. Bonnet has fully proved this fact by experiments repeated with the greateſt attention. The organ of the males is contained in the belly; it is made to come out by preſſing ſlightly upon the extremity of this part: it is generally furniſhed with two crotchets, deſigned to ſeize upon the female. The place of this organ is very various: in ſome, it is at the top of the belly and before the breaſt, as in the female of the libellula; at other times, it is at the end of the antenna, as in the male ſpider. Inſects multiply prodigiouſly: they are almoſt all oviparous, except the wood-louſe.

Inſects are produced like men: each individual has two ſexes; and the coition is double, as is obſerved in the earth-worm and ſnail.

M. Adanſon adds, that the bivalves, animals in cockles or ſhells, have no organs of generation, and reproduce their young without coition: theſe worms are viviparous. The univalves, or ſnails, are oviparous; the young having come out either from the belly of the mother or from the eggs, have their ſhell ready formed.

The polypi are the moſt ſingular animals in the act of generation; they produce by ſlips: from every polypus in full vigour a button is ſeparated, which attaches itſelf to any neighbouring body, and grows upon it: polypi are alſo formed at their ſurface, as branches which produce trunks of trees.

In generation, only the phenomena are known; and all the ſyſtems which have been invented to explain the myſtery, always preſent unſurmountable difficulties: they are found collected in Haller's Phyſiology, *la Vénus Phyſique de Maupertuis*, Buffon's Natural Hiſtory. M. Bonnet is one of the naturaliſts who has ſaid moſt upon the ſubject, in his Conſiderations upon Organiſed Bodies. M. le Count de Buffon has offered an ingenious ſyſtem; and his work ought to be conſulted.

7. Irritability is the property which certain organs, called *muſcles*, have of contracting, that is, of ſhortening by the impreſſion of a ſtimulus. M. Haller has treated excellently of this doctrine. The muſcles of man, of quadrupeds, cetacea, and birds, reſemble one another: they are all equally red, formed of fibres united in bundles of different forms, covered and furniſhed with argentine membranes called *aponeuroſes*, terminated by flat roundiſh ſtrings called *tendons*.

Among the fiſhes the muſcles are white, and much more irritable than thoſe that are red. In reptiles, irritability is ſtill ſtronger and more tenacious; it continues a long time after the death of the animal; which appears to be common to all animals whoſe blood is cold, whilſt the hot-blooded loſe this property as the blood cools.

Inſects have their muſcles placed in the heart of thin bones, which are hollow, and of the nature of horn. This ſtructure may be very well obſerved in the large green locuſt, or in the lobſter.

The muſcles of worms are very pale and irritable; they are even very ſtrong, particularly in the worms with coverings, which have a weighty ſhell to move.

The polypi are very irritable; they contract into one point; they move their arms with a ſingular agility; they fold them back very readily. Their ſtructure, however, does not appear to be muſcular. It is irritability which gives animals the power of tranſporting themſelves from one place to another, and of performing a great number of motions, in order to ſelect the hurtful things, and to procure for themſelves thoſe that are uſeful. In the hiſtory of this function, then, theſe motions ought to be conſidered; ſtanding and walking, jumping, flight, the pace of reptiles, ſwimming, are ſo many combined actions or reſults of muſcular contractions proper to each claſs of animals. A full explanation of the cauſe of ſtanding would require the examination of the muſculi extenſores of the human thigh. For leaping, we require the examination of the extremities, the form of the body, the long and acute face, and the thorax of quadrupeds, laterally compreſſed; for flying, the ſtructure of the feathers of the ſternum, pectoral muſcles, the bill, and the tail, and the inner texture of the bones of birds. For this purpoſe, it would be neceſſary to conſider in detail the muſcular rings, the ſcales or tubercles, which ſerve reptiles inſtead of feet; the form of the body, the ſtructure of the fins, that of the air-bladder, and its communication with the ſtomach, in fiſhes. In inſects, the ſtructure, the number and poſition of the feet, the appendices of the tarſi, the form, poſition, and nature of the wings, of the balancers. At preſent it is ſufficient to have ſhown the importance of theſe conſiderations, and thoſe which merit in particular the attention of phyſiologiſts.

Laſtly, there is a reflection which appears to me to have been made improperly; it is, that a muſcle may be conſidered as a ſecretory organ, deſtined for the ſeparation of the fibrous and irritable matter, which we ſhall take notice of again in another place, and that the vitiated ſtate of this ſort of ſecretion ſhould be obſerved moſt attentively by phyſicians. We ſhall reſume the conſideration of this ſubject when we come to the blood.

8. Senſibility is a function, by means of which animals ſuffer the ſenſations of pleaſure and pain, according to the nature of the bodies which are in contact with theſe organs. The ſenſes depend upon the brain, the medulla oblongata, or ſpinal marrow, and the nervous cords, or pairs of nerves, which divide into a great number from theſe three foci. Without theſe organs they can have no ſenſibility.

In order to extend the mechaniſm of this function, theſe organs may be divided into three regions, which are continued, and ſeem to be only one, which phyſiologiſts have called the *ſenſible man.* Theſe three regions are, the focus, compriſed in the brain, cerebellum, and medulla oblongata; the middle part, orcommun ication which points out the nervous cords; and the ſenſitive expanſion, or the dilated expanſion of the nerves. This extremity or expanſion preſents a various form in different organs; ſometimes it is cellular and reticular, as the ſtomach and inteſtines; ſometimes it is ſoft and pulpy, as the bottom of the eye and the labyrinth of the internal ear; then it preſents the form of papillæ, as under the ſkin, upon the tongue, the glans penis;

there it is expanded into long, ſoft, and flat filaments, as upon the naſal membrane of Schneider.

The brain of man is the moſt voluminous and moſt organiſed: hence the cauſe of its intelligence. Among quadrupeds it is much ſmaller: in recompenſe, the nerves are more ſenſible, and the ſenſations more acute, particularly that of ſmell, whoſe organ is very dilated, and as if multiplied by the number of the ethmoidal laminæ. The ſkin being thick and covered with hair, carries off the ſenſibility, and deſtroys the touch. The taſte is very nice among animals. The ear preſents the ſame apparatus as that of man. The cetacea have almoſt no brain relatively to the maſs of their bodies: this organ is encircled with an oily thick fluid: their ſenſations are obtuſe.

The brain of birds has not the ſame ſtructure and the ſame apparatus of folds, eminences, and concavities, with that of man and quadrupeds. The beautiful ſtructure of the eyes of theſe animals, their largeneſs, the thick and cartilaginous tunica ſclerotica, the inner eye-lid, membrana nictitans, moved by particular muſcles, the cryſtalline and vitreous humours, the bag of black matter contained in the extremity of the optic nerve, the brilliant covering of the choroid; all theſe announce a complete organiſation; a care taken by nature to render the ſight of birds piercing, and withal to enable them to diſcern at a diſtance their prey, and to ſhun the dangers which the rapidity of their flight might expoſe them to; in a word, to favour their agility and mobility, which ſeem to form the diviſion of theſe animals. The ſenſe of hearing is leſs perfect than their ſight: they ſeem to ſhow only a ſmall ſenſibility to the ſmell and taſte of aliments: the ſituation of the noſtrils, and the hard membrane which covers the bill, fully explain theſe phenomena.

Among reptiles ſenſibility is very ſmall. The brain is very inconſiderable; the nerves have no ganglions; the ſenſes appear in general leſs active, although the eye and internal ear preſented a very beautiful organiſation to Meſſrs Klein, Geoffroy, and Vicq d'Azir.

Fiſhes have a very ſmall brain, and their cranium is filled with an oily maſs: their ſenſes, and particularly their ſight and hearing, are very delicate. The laſt of theſe organs is very well conformed, as Meſſrs Geoffroy, Klein, Camper, and Vicq d'Azir, have obſerved. The naturaliſts who imagined that fiſhes were deaf, are therefore much miſtaken.

Inſects have no brain, but a medulla oblongata, cylindrical, and full of knots, which pervade the whole of their body.

From this medulla ſhoot nervous filaments, which accompany the diviſion of the trachea; only the eyes of inſects are known. Swammerdam has deſcribed an optic nerve, which is divided under the cornea of the eyes like a net-work, into as many filaments as there are facets in this membrane. It is uncertain if they have any organ of hearing.

Almoſt no more traces of the ſenſible organ are to be found in the worm. Swammerdam has found a brain with two lobes, and moveable in the ſnail; two eyes, placed either at the baſe or at the point of the tentacula, and the contractile optic nerve, as well as theſe kinds of horns. M. Adanſon ſays, that in worms the eyes are ſometimes awanting, or that they are covered with an opaque ſkin.

As to the polypi, they have no organ of ſenſe, tho' they ſeem to ſeek for the light.

Senſibility, then, is the function which is imparted to man in a much greater degree than to all the other animals. It is that which diſtinguiſhes and places him at their head. This function ought to be underſtood at large, by the legiſlator, philoſopher, and phyſician.

LECTURE LXIII.

Of the CHEMICAL ANALYSIS *of* ANIMAL SUBSTANCES.

THE analyſis of animal ſubſtances is the moſt difficult and leaſt advanced part of chemiſtry: Ancient chemiſts were content with diſtilling theſe ſubſtances in a naked fire; but we now know that this operation alters, and diveſts entirely of their nature, the ſo compounded bodies as the fluid or ſolid animal ſubſtances are: only a few of the humours in man, and of certain quadrupeds, have been analyſed.

Many reaſons have been advanced againſt the progreſs of this branch of chemiſtry: the difficulty and diſagreeableneſs of theſe labours; the few reſources which ſcience affords, in treating of the animal ſubſtances, without their undergoing conſiderable changes; the impoſſibility of effecting the moſt diſtant ſyntheſis, in endeavouring to reproduce theſe ſubſtances; and in particular the ſmall intereſt which the moſt chemiſts, when not phyſicians, have hitherto had in the knowledge which this analyſis might furniſh; theſe make the principal motives which have ſtopt the progreſs of this ſubject. Nevertheleſs, the reſearches of ſome moderns, particularly Meſſrs Rouelle, Macquer, Bucquet, Poulletier de la Salle, Berthollet, Prouſt, Scheele, and Bergman, have diſcovered a new ſcene, and announce, that the healing art may reap conſiderable advantages from this kind of inveſtigation.

The bodies of the principal animals, ſuch as man and quadrupeds, which we attend to in particular, are formed of fluids and ſolids. The humours of animals are diſtinguiſhed into three claſſes, relatively to their uſe. The firſt comprehends the recrementitial humours, deſtined for the nouriſhment of ſome organs: the ſecond comprehends the excrementitial humours, which are ejected from the body by certain emunctoies, as if uſeleſs, and ſuſceptible even of hurting, if too long retained. In the third, the humours are ranked, which contain the two preceding, and of which a part is recrementitial and a part excrementitial. The firſt are, the blood, lymph, gelatinous, fibrous, or glutinous parts, the fat, marrow, matter of internal perſpiration, and the oſſeous juice. The ſecond comprehend the fluid of tranſpiration, ſweat, the mucus of the noſtrils, the wax of the ears, the wax of he eyes, the tears, the urine, and the excrements. The laſt are, the ſaliva, the tears, the bile, the pancreatic juice, the gaſtric and inteſtinal juice, the milk and ſeminal liquor. As there is great need that all heſe fluids be known, we ſhall here treat of thoſe only which the chemiſts have examined.

Of the Blood.

Among the excrementitial humours, the moſt important, the moſt compounded, and the moſt incomprehenſible, is the blood. It ſhall be the firſt, becauſe, according to the doctrines of the beſt phyſicians, it is he ſource and focus of all the other animal fluids. Several phyſicians, and in particular M. Bordeu, conſidered it as a kind of liquid fleſh, and as a compound of all the animal humours. This opinion, however, although it be very probable, is not yet entirely demonſtrated.

The blood is a fluid of a fine red colour; of an uncuous fat conſiſtence, as if ſoapy; of an inſipid, ſomewhat ſaline, taſte; which is contained in the heart, areries, and veins. This fluid greatly differs, according o the regions which it runs through; and it is not the ame, for example, in the arteries and veins, in the breaſt and in the region of the liver, in the muſcles, and in the glands. This is a fact not ſufficiently atended to by chemiſts who have treated of it in their works.

Upon conſidering the blood through the whole animal kingdom, it is obſerved, that it varies ſingularly in different animals, in the colour, conſiſtence, odour, and particularly the temperature. This laſt property is the moſt important, and ſeems to depend upon circulation and reſpiration. Man, quadrupeds, and birds, have their blood hotter than the medium in which they live; for that reaſon they are called animals with hot blood. Among the fiſhes and reptiles, it is of a temperature equal to the ſurrounding medium; they are called therefore animals with cold blood. It is probable it might be the ſame caſe with the other properties of this fluid, and particularly the chemical qualities or characters, if the blood of all animals were diſtinctly known.

Human blood, which is here particularly meant, varies according to the age, the ſex, the temperament, and health. In infancy, among women and pituitous perſons, it is more pale and leſs conſiſtent; in robuſt ſtout men, it is of a deep red, almoſt black, and of a much more ſaline taſte. Phyſicians know alſo, that in perſons affected with the lues and ſcrophula, the tetters and gout, the blood is acrid, and deſtitute of taſte and ſweetiſhneſs, which are peculiar to it in the ſtate of health.

Before entering upon the analyſis of the blood, its phyſical properties muſt be known; its colour, heat, taſte, ſmell, and particular conſiſtence already mentioned. The microſcope diſcovers in it a great number of globules; which, when they are paſſing through the ſmall ducts, loſe, according to Leeuwenhoek and Boerhaave, their red colour, become yellow, and laſt of all white: ſo that, according to the Leyden phyſician, a red globule is an aſſemblage of ſeveral ſmaller white globules, and owes its colour only to the aggregation. The blood preſents alſo a ſingular phyſical property. While it is warm and in motion, it remains conſtantly fluid and red: when it is cool and in repoſe, it turns ſolid, which gradually ſeparates of itſelf into two parts; the one red, which ſwims above, of a deep colour, remaining concrete till it be altered; it is called the *craſſamentum:* the other, which occupies the bottom of the veſſel, is of a greeniſh yellow, gluey, called *ſerum* or *lymph*. This ſpontaneous coagulation and ſeparation of the two parts of the blood takes place in the laſt inſtants of animal life, and gives riſe to theſe concrete ſubſtances which are found after death in the heart and large veſſels, and which have been conſidered falſely as polypi.

Blood, expoſed to a gentle heat long continued, paſſes to the putrid fermentation. If it is diſtilled in a balneum mariæ; it yields a phlegm of an inſipid ſmell, which is neither acid nor alkaline, but which eaſily paſſes to the putrid ſtate by means of an animal ſubſtance which is diſſolved in it. Blood, very ſtrongly heated, coagulates [*], and dries gradually, as M. De-

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[*] The coagulation of blood, with all the circumſtances which attend this appearance, bears but little analogy to the conſolidation of animal jellies or of mucilaginous ſubſtances by expoſure to cold. A quantity of blood, recently drawn from a vein, coagulates in the ſame time in any degree of heat between 56° and 104° of Farenheit's ſcale: however, the coagulum formed in the higheſt degree of heat is ſomewhat firmer; ſo that cold does not ſeem in the leaſt to promote the coagulation of blood. Neither will reſt alone produce it, as appears from the experiments of Mr Hewſon, who applied two ligatures upon the jugular vein of a living animal; and upon opening the vein after a ſtagnation of two hours, he found the blood contained between the ligatures ſtill poſſeſſed fluidity. But if the air of the atmoſphere gain admiſſion to a vein, the blood inſtantly coagulates; and this change ſeems to be produced in conſequence of ſome chemical attraction, ſince all kinds of air will not produce this effect: on the contrary, the admiſſion of phlogiſticated air prevents, or at leaſt retards, the progreſs of coagulation, and diſpoſes the blood to aſſume a deeper and more purple tint of colour. This deepneſs of colour diſtinguiſhes arterial blood from venous blood: and accordingly Dr Hamilton found, that arterial blood acquired all the properties of venous blood by mixing ſome dephlogiſticated air with it.

The lymph of blood contained in the umbilical cord is made to coagulate by expoſure to 118° degrees of heat, the ſerum requires about 160°; and ſo far is cold from aiding the coagulation of haen has diſcovered: it loſes ſeven-eighths of its weight, and makes an effervеſcence with acids. It may be hardened ſufficiently by a well conducted fire, ſo as to form a kind of horny ſubſtance. If ſome dried blood is expoſed to the air, it ſlightly attracts humidity; and in ſome months a ſaline effervеſcence is formed, which M. Rouelle took for mineral alkali. Diſtilled in a naked fire, it yields an alkaline, not acid phlegm, as ſome chemiſts have pretended, and particularly Vieuſſens: then a light oil paſſes over; next an oil coloured and weighty, ſome concrete volatile alkali, or aërated ammoniacal ſalt, made impure by ſome groſs oil: a ſpongy coal remains in the retort, very difficult of incineration, in which we find ſome marine ſalt, mild mineral alkali, ſome iron, and an earthy matter, whoſe nature is not yet known.

Blood united to the alkalis becomes more fluid by repoſe. The acids inſtantly coagulate it, and alter its colour; then the neutral ſalts, formed with the mineral alkali, and any of the acids indiſcriminately employed, are extracted by filtration, evaporation, exſiccation with a gentle fire, and then by waſhing the remaining dried matter. Spirit of wine coagulates blood.

Experiments made upon recent blood do not point out the nature of the ſubſtances of which this fluid is compoſed; but the ſpontaneous decompoſition of the blood, and the ſeparation of its two parts, the craſſamentum and ſerum, affords a method of acquiring this knowledge, by examining each of theſe matters in particular. It is but a few years ſince the chemical analyſis of the blood was no farther advanced than what has been juſt now delivered; but the labours of Meſſ. Menghini, Rouelle junior, and Bucquet, have inveſtigated this humour in a very different manner; particularly the two laſt have proved in their works, to what perfection

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blood, that the blood contained in a portion of a veſſel may be frozen, and afterwards thawed without congealing, but will ſpeedily coagulate upon the admiſſion of air.

fection the analyſis of animal ſubſtances might be brought by following their footſteps. The reſearches of theſe philoſophers ſhall direct our following conſiderations of the properties of each of the ſubſtances which compoſe the blood.

The ſerum is very far from being pure water: it is a particular matter of important conſideration, to which we have given the name of *lymph*. It is of a yellowiſh white, inclining a little to green; its conſiſtence is unctuous and gluey. Expoſed to heat, it coagulates and hardens a long time before it comes to the boiling point: it turns the ſyrup of violets green. Diſtilled in a balneum mariæ, it yields a phlegm of a mild inſipid taſte, neither acid nor alkaline, but which putrefies readily: after that it is hard, dry, and tranſparent like horn: it is incapable of ſolution in water: diſtilled in a retort, it yields an alkaline phlegm, a great quantity of concrete volatile alkali, and a very fetid thick oil. All theſe products have in general a very fetid particular odour. The coal of the lymph, diſtilled in a naked fire, fills the retort almoſt entirely. It is ſo difficult of incineration, that it muſt be kept burning for ſeveral hours, and a great ſurface muſt be preſented to the air, before it be reduced to aſhes. Theſe are of a blackiſh grey, containing marine ſalt, mineral alkali, often a little iron, and an earthy matter, which has not yet been properly examined. Might not this earthy matter be perhaps a kind of neutral phoſphoric ſalt like the baſe of the bones?

The lymph, expoſed for ſome time to a warm temperature in an open veſſel, paſſes eaſily to putrefaction, and then gives a great quantity of concrete volatile alkali of an inſupportable ſmell. It putrefies ſo rapidly, that M. Bucquet could not aſcertain if it paſſed to the acid fermentation before it became alkaline. This liquor unites with water in all proportions; then it loſes its conſiſtence, taſte, and greeniſh colour: the mixture muſt be agitated to favour the combination, as the different denſity of theſe two fluids is an obſtacle to their union. The lymph, poured into boiling water, coagulates in great meaſure, and inſtantly. A portion of this fluid forms with the water a kind of an opaque and milky white liquor; which has, according to M. Bucquet, all the characters of milk, viz. which grows ſour like this fluid, coagulates by heat, the acids, &c.

The alkalis united with the lymph render it more fluid, occaſioning a kind of ſolution. The acids alter it in an oppoſite manner; they give it conſiſtence, and coagulate it. Upon filtrating this mixture, and evaporating the fluid obtained by this filtration, we obtain that neutral ſalt which the acid employed ſhould form with the mineral alkali; which proves that this laſt ſalt exiſts uncombined, and poſſeſſing all its properties in the lymph. The coagulum, formed in this liquor by the addition of an acid, diſſolves very readily in the volatile alkali, which is the true ſolvent of the lymph; but it does not diſſolve at all in pure water: an acid ſeparates the lymph united with the volatile alkali. The ſame coagulum, diſtilled in an open fire, yields the ſame products as pure dried lymph; and its coal contains a great deal of mineral alkali: which proves, according to M. Bucquet, that there is a portion of this ſalt intimately combined in the lymph, which the acid employed to coagulate it does not ſaturate.

Lymph does not decompoſe the argillaceous and calcareous neutral ſalts; but it decompoſes very well the metallic ſalts. It is coagulable by ſpirit of wine: this coagulum differs greatly from that which is formed by the acids in its ſolubility in water, according to the diſcovery of M. Bucquet. Therefore, from theſe details, the lymph appears to be an animal mucilage, compoſed of water, oil, marine ſalt, mild mineral alkali, and an inſoluble matter, which has been conſidered as a particular earth, although it is perhaps an earthy ſalt. The moſt ſingular property of this mucilage, and one which merits the attention of phyſicians, is that of becoming concrete by the action of heat.

The craſſamentum, expoſed to heat in a balneum mariæ, yields an inſipid water; it dries and becomes brittle. In a retort it yields an alkaline phlegm, a thick oil of a fetid and empyreumatic ſmell, and much concrete volatile alkali. Its reſiduum is a ſpongy coal, of a brilliant and metallic aſpect, difficult of incineration, and which, when heated with the vitriolic acid, yields Glauber's ſalt and martial vitriol. After this operation, it yields an earth unknown. The craſſamentum putrefies very readily in warm air. When it is waſhed with water, this fluid ſeparates into two very diſtinct matters; the one, which it diſſolves, communicates to it a red colour. This ſolution, treated by different menſtrua, preſents all the characters of the lymph; but it contains a much greater quantity of iron. This metal is extracted by incineration, and by waſhing the incinerated coal, to ſeparate the ſaline matters. The reſiduum of this ley is in the ſtate of crocus martis, of a beautiful colour: it is generally attractible by the magnet. The colour of the blood is attributed to this metal. Iron in very great quantity has been extracted from this fluid by Meſſrs Menghini, Rouelle, and Bucquet.

The craſſamentum, after having been waſhed and deprived of all the red lymph it contained, is in the ſtate of a fibrous white matter, which remains to be examined.

The fibrous part of the blood is white and colourleſs when it is well waſhed; it has only an inſipid taſte. By diſtillation in a balneum mariæ, an inſipid phlegm, ſuſceptible of putrefaction, paſſes over. The moſt gentle heat ſingularly hardens the fibrous matter. When it is expoſed to a briſk heat, it contracts like parchment: diſtilled in a retort, it yields an alkaline phlegm, a heavy, thick, and very fetid oil, much concrete volatile alkali, tainted by a portion of oil. Its coal is not large, but compact, weighty, leſs difficult to incinerate than that of the lymph. It cinder is very white; it contains no ſaline matter, which has been carried off by the waſhing of the craſſamentum, nor iron; it is a kind of reſiduum, whoſe aſpect is earthy, but whoſe nature has not been examined.

The fibrous part putrefies very quickly, and with great facility. When it is expoſed to a warm and moiſt air, it ſwells, and yields much volatlle alkali. It is inſoluble in water. When it is boiled with this fluid, it hardens and acquires a grey colour. The alkalis do not diſſolve it; but even the weakeſt acids combine with it. The nitrous acid, concentrated, diſſolves it with efferveſcence and the diſengagement of nitrous gas; it forms with it a yellowiſh mucilage. With ſpirit of ſalt it yields a kind of green gelly. The acid of vingar diſſolves it by means of heat: water, and particularly the alkalis, precipitate the fibrous part united with the acids. This animal matter is decompoſed in theſe combinations; and when it is ſeparated from the acids by any means, it does not preſent the ſame properties. The neutral ſalts, and other mineral ſubſtances, have no action upon it. It unites with the lymph, particularly that which is coloured, to form the craſſamentum. This laſt is ſoluble entirely in the acids, as the fibrous part is, on account of the combination of this matter with the red lymph. Hence it is evident, that the fibrous part is widely different from the *lymph*, properly ſo called. This is a ſubſtance more animalyſed than this laſt; a ſort of animal gluten, which has great relation with that of the farina, and particularly which has the very remarkable property of becoming concrete by cooling and repoſe. It cannot be doubted, that this ſubſtance, which has not yet been ſufficiently diſtinguiſhed from the lymph by phyſiological and pathological authors, is of particular conſequence in the animal-œconomy. Might not this be what is depoſited in the muſcles, and that which conſtitutes the fibrous part of theſe organs, and the ſubſtance irritable from its excellence? If this aſſertion were as fully demonſtrated, as it is probable, ſhould it not be important to pay more attention to this ſubſtance than has yet been done, and to regard it as capable, by its abundance or deficiency, of inducing particular diſeaſes? I ſhall have occaſion ſome other time to reſume this important ſubject.

Notwithſtanding all theſe reſearches about the blood's properties, all its chemical qualities are very far from being known. It is uncertain what is the difference between the lymph and the fibrous part. The blood has not been examined in all its ſtates; and eſpecially in the different diſeaſes, in which this fluid ſuffers conſiderable alterations, viz. in ſtrong inflammations, in the chloroſis, &c. Phyſicians are more acquainted with it in this point of view than chemiſts. M. Rouelle has examined the blood of ſome quadrupeds, as the ox, the horſe, the calf, the ſheep, the ſow, the aſs, and goat. They all yield the ſame products as that of man, but in different proportions.

LECTURE LXIV.

Of the MILK.

MILK is a recrementitial humour, deſtined for the nouriſhment of young animals in the firſt ſtages of life. It is of a dirty white; of a ſaccharine ſweet taſte; of a ſlightly aromatic ſmell. It is ſeparated immediately from the blood in the female mammæ of animals: it is conveyed principally by the mammary arteries. Man, quadrupeds, and the cetacea, are the only animals which give milk. All other animals want the organs which are deſtined for the ſecretion of this humour.

Milk differs greatly in the different kinds of animals: in women it is very ſaccharine; that of cows is ſweet, and its principles are well united: thoſe of the goat and aſs have a particular virtue; they are often ſlightly aſtringent. As to its other properties, its differences depend generally upon the aliments which nouriſh the animals.

Cow milk, which we ſhall make our example in this analyſis, becauſe it is eaſily procured, is a compound of three different ſubſtances; ſerum, which is fluid and tranſparent; the butter and cheeſe, both of which have a greater conſiſtence. Theſe three parts are mixed and ſuſpended, ſo that they form a kind of animal emulſion.

Milk, expoſed to the action of heat, and to a balneum mariæ, yields a taſteleſs phlegm, of a weak ſmell, and ſuſceptible of putrefaction. With a little ſtronger heat it coagulates like the blood, according to the obſervations of M. Bucquet. By agitation and gradual exſiccation, it forms a ſort of ſaccharine extract. This extract diſſolved in water conſtitutes the weak milk of Hoffman. Diſtilled in a naked fire, this extract yields ſome acid, fluid oil, concrete oil, and volatile alkali. Its coal contains very little fixed vegetable alkali, febrifugal ſalt, and a earth little known.

Milk, expoſed to a warm temperature, is ſuſceptible of the ſpirituous fermentation, and of forming a kind of wine; but it muſt be in great quantity. The Tartars prepare a ſpirituous liquor with the milk of mares. Milk paſſes to the acid ſtate readily, and then it coagulates. The cheeſy part forms into a maſs, and the ſerum ſeparates.

The acids inſtantly produce the ſame effect upon milk: they coagulate it: the alkalis, and eſpecially the volatile, rediſſolve the coagulum. Boerhaave ſays, that in boiling milk with oil of tartar, this fluid becomes yellow, then red, and of the colour of blood. He thinks alſo, that it is a ſimilar combination which converts the milk to the ſtate of true blood in the human body.

Weak milk is prepared by heating ordinary milk along with runnet. This ſubſtance formed by the milk, rendered ſour in the ſtomach of calves, is a ferment which coagulates the cheeſy part. When this coagulum is formed, the milk is paſſed through a cloth. The herb gallium and thiſtles act as runnet does upon milk.

Serum prepared in this manner is turbid; it is clarified by means of the white of an egg and cream of tartar; it has a ſweet taſte; it contains a ſaccharine eſſential ſalt, a gelatinous matter little known, a colouring extractive ſubſtance, and ſome febrifugal ſalt diſſolved in a great quantity of water. In order to ſeparate theſe principles, the water is volatiliſed by evaporation to the conſiſtence of ſyrup; it is left to cool; a ſalt at firſt a little red cryſtalliſes, which is the ſugar of milk, and is purified by new ſolutions and cryſtalliſations. This ſalt cryſtaliſes nearly like vitriolated tartar: it has an earthy and a moderately ſaccharine taſte; it diſſolves in one part and a half of hot water; it yields to diſtillation an acid phlegm, a light oil, a ſpongy coal, which contains very little fixed alkali; it is very difficult of incineration. It does not ſeem ſuſceptible of paſſing *per ſe* to the ſpirituous fermentation; but when it is combined with the cheeſy matter and the gelatinous mucilage, it may form a kind of wine, ſince M. Spielman has proved by fair experiments, that milk fermented in a great maſs yielded ardent ſpirit by diſtillation.

From ſerum a new quantity of ſaccharine matter may be obtained by a ſecond, and even a third evaporation. The mother-water which remains is gluey; it turns frequently into a gelly by cooling, as M. Rouelle has obſerved; it contains a gelatinous mucilage, an extractive matter, and febrifugal ſalt, which is extracted by a new ſolution and evaporation. This ſalt may be detected alſo by oil of vitriol.

The ſugar of milk, expoſed to an open fire, fuſes, bubbles up, and burns like ſugar. It emits a ſmell of caramel; its coal is difficult of incineration; it yields very little aſhes, as a pound of the ſugar of milk furniſhed M. Rouelle only about twenty-four or thirty grains. This cinder contains febrifugal ſalt and a little vegetable fixed alkali, which this chemiſt aſcribed to the extractive matter. M. Vulgamoz found, according to M. Pœrner, the ſame analogy as M. Rouelle, between the ſalt of milk and ſugar.

The cheeſe forms into a maſs, and ſeparates from the other parts of the milk by the action of heat, by the acid fermentation which this liquor is capable of undergoing, and by the mixture of acids. This matter, when well waſhed, is white, ſolid, as if fibrous: the action of a gentle fire hardens it. Diſtillation in a balneum mariæ extracts from it an inſipid phlegm, which putrefies.

Dried cheeſe, diſtilled in a retort, yields an alkaline liquor, a heavy oil, and much concrete volatile alkali. Its coal is denſe, very difficult of incineration, and yields no fixed alkali.

Cheeſe putrefies in a warm temperature: it bubbles up, emits a diſagreeable ſmell, puts on a ſemifluidity, becomes covered with a ſcum, owing to the diſengagement of a ſtrongly-ſmelling and very mephitic gas, which eſcapes with difficulty from this viſcous matter.

Cheeſe is inſoluble in cold water; hot hardens it.

The alkalis diſſolve it; and particularly the volatile, which, poured into milk coagulated by an acid, in the doſe of a few drops, very ſoon reſolves the coagulum.

The acids, concentrated, alſo diſſolve it.

The neutral ſalts, and particularly marine ſalt, retard its putrefaction.

It appears from all theſe details, that cheeſe is a ſubſtance akin to the lymph; but as from its nature it is not ſoluble in water, it is by means of the gelatinous ſubſtance, and of the extractive and ſaccharine matters contained in the ſerum, that it, as well as the oily part, is kept in ſolution.

Butter partly ſeparates from the milk by repoſe; it collects at its ſurface; but as it is mixed with much ſerum and cheeſy matter, it is completely ſeparated from them by a rapid motion: this conſtitutes the art of beating butter. The ſerum, which ſwims above the beat-butter, retains a portion of this oily ſubſtance; it is yellow, ſour, and greaſy; it is called *butter-milk.* Cream is a mixture of cheeſe and butter taken from the top of the milk. It is of much more difficult digeſtion than milk. This ſubſtance is ſuſceptible of lathering by a great agitation. In this ſtate it is the whipt cream.

Pure butter is concrete and ſoft, of a golden yellow colour, of a ſweet agreeable taſte. It is a fat oil, rendered concrete by an acid: it fuſes with a gentle heat, and becomes ſolid by cooling. Diſtilled in a balneum mariæ, it yields an almoſt inſipid phlegm. In a retort, it gives over an acid of a very pungent ſtrong odour; an oil at firſt fluid; then a concrete coloured oil, of the ſame pungent odour as the acid. By rectifying theſe products, the oil is rendered fluid and as volatile as the eſſential oils. Only a ſmall quantity of coal remains.

Butter eaſily becomes acid and rancid in a hot air. Its acid is then evolved, and it has a diſagreeable taſte: Water and ſpirit of wine bring it back to its former ſtate, by diſſolving the acid. The fixed alkali diſſolves butter, and forms with it a kind of ſoap little examined.

From theſe details it is evident, that butter is an oily matter, of the nature of the vegetable concrete fat oils.

Freſh butter is ſweet, relaxing, and cooling: but it eaſily ſours, and in general agrees ill with moſt ſtomachs. Red butter, whoſe acid is evolved, is one of the moſt unhealthful aliments, and of the moſt difficult digeſtion.

Milk is an agreeable and uſeful aliment in many caſes. It is alſo one of the moſt valuable medicines which medicine poſſeſſes. It ſweetens the acid humours in diſeaſes of the ſkin and joints; ſuch as the rheumatiſm, gout, &c. It cicatriſes ſome ulcers of a good nature. It may be impregnated with ſome aromatic parts; and is then an excellent medicine in the phthiſis pulmonalis. All ſtomachs do not digeſt milk. When acidities exiſt in the firſt paſſages, it is generally hurtful. It generally requires great prudence in its adminiſtration. We uſe, ſometimes with ſucceſs, milk rendered medicinal by certain ſubſtances which we give to the animal which furniſhes it.

The milk of different animals has ſome particular virtues. That of women is mild, very ſaccharine, and agrees well in the maraſmus. Aſs-milk is ſucceſsfully employed in the phthiſis pulmonalis and gout: generally it is relaxing. Mare's milk approaches to aſs's milk. Goat-milk is ſerous and ſlightly aſtringent. Cow-milk is the thickeſt, fatteſt, and moſt nouriſhing: it is alſo the moſt difficult of digeſtion; and it is often neceſſary to take a little water along with it, or ſome aromatic infuſion, particularly if it is nauſeous and provokes vomiting.

Milk is employed alſo externally, as ſoftening and emollient. It readily calms pains; it ripens collections of matter and abſceſſes, and accelerates their ſuppuration. It is applied hot, and contained in a bladder, upon the affected parts.

LECTURE LXV.

Of the FAT.

THE fat is an oily concrete matter contained in the cellular texture of animals; it is white or yellowiſh, generally of an inſipid ſmell and taſte: in all animals it differs in ſolidity, colour, taſte, &c. Age alſo increaſes theſe differences: in infancy it is white, inſipid, and not very ſolid; in the adult it is firm and yellowiſh; in old age its colour is deeper, its conſiſtence very various, and its taſte in general more ſtrong.

That of man and quadrupeds is conſiſtent, white or yellow; that of birds is more fine, ſweet, unctuous, and in general leſs ſolid; among the cetacea and fiſhes it is almoſt fluid, and often placed in particular reſervoirs, as in the cavity of the cranium. It is found in reptiles, inſects, and worms; but in theſe animals it accompanies only the viſcera of the lower belly, upon which it is laid in knots, only a ſmall quantity is found upon the muſcles and under the ſkin.

It has been obſerved, that the fat of frugivorous and herbivorous animals is firm and ſolid, whilſt that of the carnivorous is more or leſs fluid. It muſt be, however, remarked here, that the fat is always leſs ſolid and concrete in a living and warm animal than it appears to be in a dead one, when cold and ſubmitted to diſſection.

The fat varies alſo, according to the different places of the body of the animal which conceal it: it is ſolid about the reins and under the ſkin; it is leſs ſo between the muſcular fibres, or in the neighbourhood of the moveable viſcera, ſuch as the heart, ſtomach, inteſtines: it is more copious in the winter than ſummer: it ſeems to be deſtined to ſupport the heat in the regions where it is placed; as many facts collected by phyſiologiſts demonſtrate: it appears even to contribute to the nouriſhment of animals, as is obſerved in the bears, monkeys, rats; and in general all animals ſubjected to long abſtinence, among which the fat melts, and is gradually deſtroyed.

When we want greaſe for pharmaceutical purpoſes, or for the examination of its chemical properties, it muſt be cut into pieces; the membranes and veſſels which run through it muſt be ſeparated, then waſhed with a great quantity of water: it is melted in a new earthen veſſel, water being gradually added: when this fluid is diſſipated, and no more boiling is excited, it is put into an earthen veſſel, where it fixes.

All the chemical properties of fat have not yet been inveſtigated. The action of heat, air, and two or three menſtrua, only are known. However, it is one of the animal-matters which is the moſt neceſſary to be known, to enable us to judge of its uſes, of which we know nothing

thing certain, and particularly of the alterations which it is ſuſceptible of undergoing in living bodies.

The fat of any animal whatever, expoſed to a gentle fire, liquefies, and then congeals by cooling. If it is ſtrongly heated, and with the contact of air, it emits a fume of a pungent odour, exciting tears and coughing, and it enflames when it is hot enough to be volatiliſed: it yields but a ſmall quantity of coal. If it is diſtilled in a balneum mariæ, a vapid water is got over, of a ſlight animal odour, which is neither acid nor alkaline, but which very ſoon acquires a putrid ſmell, and which depoſites as if mucilaginous filaments. This phenomenon, which takes place in the water obtained by the diſtillation of all animal-ſubſtances in a balneum mariæ, proves, that this fluid carries along with it ſome mucous principle, which is the cauſe of its alteration. Fat diſtilled in a retort gives over a phlegm, at firſt aqueous, then ſtrongly acid; an oil, partly liquid and partly concrete: there remains a very ſmall quantity of coal, very difficult of incineration. Theſe products have an acid, pungent, penetrating ſmell, as ſtrong as that of the ſulphureous acid; the acid is of a particular nature, and has not yet been examined. The concrete oil may be rectified by repeated diſtillation, ſo as to be very fluid, volatile, and penetrating; in a word, to exhibit all the marks of a true eſſential oil.

Fat, expoſed to a hot air, is very readily altered: however ſweet and deſtitute of ſmell when it is freſh, it becomes ſtrong and pungent; it turns rancid: this alteration ſeems to be a real fermentation, which evolves the acid and ſets it free. It is not the oily part of the fat which occaſions this ſort of change, but a particular animal-mucilage, which a farther analyſis will ſhow. Rancid fat may be corrected in two ways: water alone is capable of carrying off the acid which it contains, as M. Pœrner has obſerved; ſpirit of wine aſo has the ſame property, according to M. de Machy. This proves, that the acid of rancid ſat puts this ſat matter into a kind of ſoapy ſtate, and thus renders it ſoluble in water and ſpirit of wine. Theſe two fluids, then, may be ſucceſsfully uſed to deprive fat of its rancidity.

When fat is waſhed with a great quantity of diſtilled water, this fluid diſſolves a gelatinous matter, which may be demonſtrated by evaporation; but the fat always retains a certain portion of this matter, which is intimately combined with it, and upon which depends its fermenting property. The action of water upon this animal-ſubſtance has not been determined.

We are ignorant how lime and magneſia act upon greaſe; we know the alkalis combine with it, and form ſoap. The acids alter and burn it, as they do the fluid oils; they are capable even of converting it into the ſtate of an acid ſoap, ſoluble in water.

Sulphur unites very well with fat, and forms a combination which has not yet been fully examined.

Fat is ſuſceptible of diſſolving certain metals: it is alloyed with mercury in the preparation called *unguentum mercuriale.* The metal is triturated with hog's-lard for a ſufficiently long time: the mercury is divided, attenuated, and united ſo intimately with the fat, that it communicates to it a ſlaty colour, and it appears no longer in a metallic form. However, this union ſeems to be only an extreme diviſion; or, at moſt, there is only a ſmall portion of the mercury diſſolved by the acid of the fat; ſince, by means of a microſcope, globules of mercury are always perceived in the beſt prepared ointment.

Lead, copper, and iron, are the three metals which are the moſt alterable by fat; their calces likewiſe combine very eaſily with it: therefore it is dangerous to keep aliments prepared with greaſe in copper veſſels, and even in earthen ones whoſe covering contains glaſs of lead.

The moſt part of vegetable matters are capable of uniting with fat: the extracts and mucilages give it a kind of ſolubility, or at leaſt favour its ſuſpenſion in water. It combines in all proportions with oils, and communicates to them a part of its conſiſtence.

Such are the known chemical properties of fat: they ſhow us, that this ſubſtance is very ſimilar to butter; that is, it is a kind of fat oil rendered concrete by a portion of acid.

As to its uſes in the animal-œconomy, beſides the heat which it ſupports in the parts which are adjacent; beſides the round, flexible, and agreeable forms, and the whiteneſs which it gives the ſkin; it ſeems alſo, according to M. Macquer, to ſerve the purpoſe of abſorbing the ſuperabundant acids which may be found in the bodies of living animals, and it is as if the reſervoir of theſe ſalts. It is known, however, that a very great quantity of acid, introduced into the body of an animal, diſſolves and melts the greaſe, which is owing ſurely to its converſion into a kind of ſoap, and to its rendering it more ſoluble.

The exceſſive abundance, and particularly the alterations of the fat, produce in the animal-œconomy fatal diſeaſes, whoſe ſymptoms and effects have not yet been fully examined. M. Lorry is particularly buſy about this ſubject; and he has eſtabliſhed between this ſubſtance and the bile a ſtriking analogy. He has given ſeveral memoirs upon this ſubject, which will be printed among thoſe of the Royal Society of Medicine.

Fat is alſo uſed as a ſeaſoner to our food: it is nouriſhing to perſons who have a good ſtomach. In medicine it is uſed externally as an emollient and anodyne: it enters the compoſition of ſeveral ointments and plaſters.

Of the Bile.

THE bile or gall is a fluid, of a more or leſs yellowiſh green colour; of a very bitter taſte; of an inſipid diſagreeable odour, which is ſeparated from the blood in a glandular viſcus, known to every body by the name of *liver*. In the greateſt number of animals, except inſects and worms, it is collected in a membranous reſervoir adjoining to the liver, called *gall-bladder*. Human bile has not been accurately examined, from the difficulty of procuring a great quantity: it is ox-bile which has ſerved for all our chemical experiments.

This liquor is of a conſiſtence almoſt gelatinous or glairy; it is ropy, like a moderately clear ſyrup: by agitation, it lathers like ſoapy water.

If it is diſtilled in a balneum mariæ, it yields a phlegm which is neither acid nor alkaline, but which is capable of turning putrid in a certain time. This phlegm often preſents a ſingular character; that of exhaling a very remarkable ſweet ſmell, very analagous to that of muſk or amber. This phenomenon has been ſhown in my own courſes; and ſeveral perſons have ſince confirmed it. When all the water which the bile contains has been extracted in a balneum mariæ, it is found in the ſtate of an extract more or leſs dry, of a dirty green and brown colour. This bilious extract attracts humidity from the air; it is very tenacious and pitchy, and it is entirely ſoluble in water. By diſtillation in a retort, it yields ſome volatile alkali, an empyreumatic animal oil, and much concrete volatile alkali. After this operation, a very voluminous coal remains, leſs difficult of incineration than thoſe hitherto ſpoken of. According to M. Cadet, who has given a very excellent paper upon the analyſis of the bile, in the Memoirs of the Academy, 1767, this coal contains mineral alkali, a ſalt which he imagines is of the ſame nature with the ſugar of milk, an animal-earth, and a ſmall portion of iron. It muſt be obſerved, that the diſtillation muſt be conducted ſlowly, becauſe this ſubſtance bubbles up conſiderably.

Bile, expoſed to a warm temperature, is very readily altered: its ſmell at firſt becomes more and more diſagreeable and nauſeous; its colour is deſtroyed; it precipitates whitiſh mucilaginous flocci; it loſes its viſcidity, and very ſoon aſſumes a fetid and pungent odour.

When its putrefaction is far advanced, its ſmell becomes ſweet like amber.

Bile diſſolves very well in water.

The acids decompoſe it like ſoaps: they occaſion a coagulum. If this mixture is filtrated, and the filtrated liquor evaporated, a neutral ſalt is obtained, formed by the acid employed and the mineral alkali; that is, Glauber's ſalt with vitriolic acid, rhomboidal nitre with the nitrous acid, and marine ſalt with muriatic acid. This excellent experiment, due to M. Cadet, demonſtrates the preſence of the mineral alkali in the bile. The ſubſtance remaining upon the filtre in theſe experiments is thick, viſcous, very bitter, and inflammable; its colour and conſiſtence vary, according to the nature and the degree of concentration of the acid employed in its ſeparation. I have obſerved, that the vitriolic acid gives it a deep green colour, the nitrous a brilliant yellow, and the muriatic a beautiful clear green. This precipitate is a true reſin: it bubbles up, melts, and kindles upon burning coals; it totally diſſolves in ſpirit of wine; and water precipitates it as it does the reſinous juices. The action of the acids upon bile, then, demonſtrates, that this humour is a true ſoap, formed by an oil of the nature of reſins, united with the mineral fixed alkali.

The neutral ſalts, mixed with bile, prevent its paſſing to the putrefactive ſtate.

The metallic ſolutions are decompoſed by the bile, which they decompoſe at the ſame time: the fixed alkali of this humour unites with the acid of the ſolution; and the oil of the bile precipitates with the metalic calx.

Bile eaſily unites with the oils, and takes them out of ſtuffs as ſoap does.

It diſſolves in ſpirit of wine: this ſolution is of a greeniſh yellow; it depoſites a gelatinous matter, which made a part of the bile, and which is inſoluble in ardent ſpirit. The tincture of bile is not decompoſed by water; which demonſtrates, that this ſubſtance is a true animal-ſoap, equally ſoluble in aqueous and ſpirituous menſtrua. Ether alſo diſſolves it very readily.

Vinegar decompoſes bile like all the acids; upon evaporating the filtrated ſolution, a mineral acetous ſalt, well cryſtalliſed, is obtained.

From theſe different experiments it follows, that the bile is a compound of a great quantity of water, of an aromatic ſpiritus rector, a gelatinous mucilage, of an oil of the nature of the reſins, and of mild mineral alkali. M. Cadet found in it a ſalt of the nature of ſugar of milk. Beſides that, M. Poulletier de la Salle, to whom anatomy and animal chemiſtry are much indebted, found in human bile, or rather in biliary calculi, which are only bile thickened and concrete, a ſalt of a particular nature, which we ſhall ſpeak of preſently.

Bile, conſidered in the animal-œconomy, is a fluid which ſeems to ſerve the office of digeſtion. Its ſoapy quality renders it capable of uniting the oily matters with water. Its bitter taſte ſhows, that it ſtimulates the inteſtines, and promotes their action upon the aliments. M. Roux, a celebrated phyſician and chemiſt of the Faculty of Medicine of Paris, who to the loſs of theſe two ſciences died too ſoon, imagined, that the bile had ſtill a principal uſe, that of ejecting from the body the colouring part of the blood. Perhaps this humour itſelf is decompoſed in the duodenum by the acids, which are almoſt always evolved in digeſtion; it is certain at leaſt that it is very much altered, particularly in its colour, as it makes a portion of the excrements, which it colours. On this account, phyſicians draw very uſeful inductions from the inſpection of the fæces, to know what is the ſtate of the bile, and that of the liver which ſeparates it. The extract of ox-bile and of ſeveral other animal-matters is employed as a very good ſtomachic. It ſupplies the defect and inertia of the bile; it gives tone to the ſtomach, and re-eſtabliſhes the functions of this weakened viſcus: but its uſe requires caution,

becauſe

becauſe it is acrid and heating; and it ought not to be given unleſs in a ſmall doſe, eſpecially to ſenſible and irritable perſons.

Of the Biliary Calculi or Stones.

WHENEVER human bile is ſtopt in its veſicula by any cauſe, and particularly by ſpaſmodic contractions, as in the melancholia, hyſteria, long vexations, &c. it thickens and produces brown, light, inflammable concretions, of a very bitter taſte, which are called *biliary calculi*. Theſe concretions are frequently in great number; they diſtend the veſicula; they ſometimes fill it entirely; they produce violent hepatic colics, vomitings, jaundice, &c.

Theſe calculi have been examined by M. Poulletier de la Salle. He obſerved that they were ſoluble in ardent ſpirit. Having ſet theſe ſtones to digeſt in ſpirit of wine, he remarked that this liquor was in a little time filled with minute, brilliant, and cryſtalliſed particles, having all the appearance of a ſalt. The experiments which he made upon this ſubject ſhowed him, that it was an oily ſalt, analogous in ſome properties to the acid ſalt, which we have examined before under the article *Flowers of benzoin*. From the inveſtigations of this philoſopher, this ſalt is contained only in the biliary calculi of man: it was not found in thoſe of the ox.

The diſcovery of M. Poulletier de la Salle comes to be in part confirmed by facts collected by the Royal Society of Medicine, particularly upon the ſtones of the veſicula fellis. This company has received from ſeveral phyſicians biliary calculi of a particular nature, which have not yet been deſcribed. They are collections of tranſparent cryſtalline laminæ, ſimilar to mica or talc, which have abſolutely the ſame form as the ſalt formed by M. Poulletier. It appears alſo, that human bile may yield a great quantity of theſe cryſtals; ſince the Society of Medicine has in its collection of calculi a veſicula fellis, entirely filled with this tranſparent ſaline concretion. A full deſcription of theſe calculi may be found in the third volume of this company. It is to be wiſhed, that the nature of theſe calculi were examined: reſearches of this kind can be of uſe only to medicine.

From theſe details it is proper that two ſorts of biliary calculi be diſtinguiſhed: the one is opaque, fragile, inflammable, and truly bilious; it is a ſort of natural bilious extract. The other is tranſparent, cryſtalliſed in laminæ; and they appear to be a ſaline principle contained in the bile, which exiſts perhaps in greater quantity in certain morbific affections of this fluid, than in the natural ſtate; and which in this caſe is diſpoſed to precipitate and cryſtalliſe whenever the bile is ſtopt in great quantity in the veſicula,

Of the Saliva and Pancreatic Juice.

Anatomists and phyſiologiſts have found a great analogy between the ſaliva and pancreatic juice. The ſalivary glands and the pancreas have indeed a ſtructure quite analogous; and the uſe of the humour which theſe organs prepare appears to be the ſame. Man and quadrupeds appear to be the only animals in which this humour is ſecreted; at leaſt ſalivary glands have not been found in moſt of the other animals.

Chemiſts have no exact knowledge on this ſubject. There is nothing the cauſe of this but the extreme difficulty of procuring even a very ſmall quantity. We only know, that the ſaliva is a very fluid juice, ſecreted by the parotid and ſeveral other glands, which runs continually into the mouth, but in greater abundance in maſtication. This humour ſeems to be ſoapy, impregnated with air, which renders it frothy; it leaves only very little reſiduum when it is evaporated to dryneſs. Salivary concretions, however, are ſometimes formed in the canals, which ſerve for the conveyance of this humour into the mouth. It appears to contain an ammoniacal ſalt, as lime and the cauſtic fixed alkalis diſengage

from

from it a pungent and urinous odour. Dr Pringle's experiments ſhow that it is very ſeptic, and that it favours digeſtion by commencing a putridity in the aliments *.

Of

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* All the fluids employed in the digeſtion of the food have been particularly mentioned by M. Fourcroy, except the gaſtric liquor, which poſſeſſes the moſt curious properties, though perhaps its chemical nature is the leaſt underſtood. A liquor of this kind, acting as a ſolvent, has long been known to exiſt in the ſtomachs of all animals with membranous ſtomachs, capable of diſſolving the food upon which the animals lived. M. Reaumur made a number of experiments upon the digeſtive powers of a hawk's ſtomach, by incloſing a variety of ſubſtances in a metallic tube perforated with holes: and the reſult of all his experiments was, that the gaſtric liquor of the hawk was capable of diſſolving fleſh, bones, and moſt animal ſubſtances; but that it had no effect upon the roots, leaves, and ſeeds of plants, or upon any of the vegetable matters upon which the herbivorous animals feed. Similar experiments have alſo been made upon dogs, and other animals, the ſtructure of whoſe ſtomachs reſembles the ſtructure of the human ſtomach, which lead to the ſame concluſion: ſo that there was every reaſon to infer from analogy, that the proceſs of digeſtion was conducted after the ſame manner in the human ſtomach. This conjecture was not however brought to the teſt of experiment, until Dr Edward Stevens got an opportunity to try the fact upon a Hungarian traveller, who could ſwallow large ſtones without hurting his health.

Dr Stevens gave him a variety of ſubſtances to ſwallow, incloſed within ſilver balls which had holes pierced in them. The balls paſſed through the whole courſe of the alimentary canal in the courſe of 30 hours; ſome days the time was longer, others ſhorter. Upon examination, the different ſubſtances were found to have been attacked by the gaſtric liquor, and to be partially diſſolved; at other times they were completely diſſolved, or reduced into the conſiſtence of a pulpy maſs; but at no time were they ever found to emit any thing of a fetid ſmell, or to be in the leaſt tainted with corruption. The fleſh of quadrupeds, birds, and fiſhes, apples, potatoes; all of them, both raw and cooked, were expoſed to the action of the gaſtric liquor, and all were diſſolved. The gaſtric liquor was not able to diſſolve bones; and ſome of the leguminous ſeeds were little affected by its action.

The reſt of theſe curious experiments will be met with in Dr Stevens's Theſis, publiſhed at Edinburgh in the year 1777.

It ſeems, however, moſt extraordinary, that ſo powerful a menſtruum of animal ſubſtances ſhould not act upon the ſtomach itſelf,

which

Of the Seminal Fluids.

THE chemical nature of the ſeminal fluid is ſtill leſs known than that of the two preceding fluids. The few obſervations which it has been poſſible to make upon this humour, have ſhown, that it approached to animal mucilages; as it became fluid by cold and by heat, and as the action of the fire reduced it into a dry and friable ſubſtance.

Anatomical and microſcopical obſervations have gone farther than chemical experiments. They have demonſtrated, that the ſemen is an ocean in which ſmall round bodies ſwim, endued with a rapid motion, conſidered by ſome as living animals deſtined to reproduce the ſpecies; and by others as organic molecules, proper for forming by their approach a living animal. But we muſt aſſert, that theſe elegant experiments have contributed nothing to the advancement of ſcience, and that they have given riſe only to ſome ingenious conjectures.

LECTURE LXVI.

Of URINE.

URINE is a tranſparent excrementitious fluid, of a citron yellow, of a particular ſmell, and ſaline taſte, ſeparated from the blood by two glandular viſcera, called

which is continually expoſed to the action of the gaſtric liquor. This power of reſiſting ſolution has been by Mr Hunter aſcribed to the living principle of the ſtomach, which enables it to reſiſt digeſtion. Mr Hunter was led to this opinion, by finding the ſtomach of a perſon who died a violent death, without any previous complaint, partly diſſolved, and partly reduced into a pulpy maſs. The body was opened ſoon after death; and in ſimilar caſes the ſame appearance has occurred to other obſervers.

We are therefore, from conſideration of all the facts, to regard the gaſtric liquor as a very curious chemical ſolvent, diſtinguiſhed by peculiarities which we do not find to prevail in any other menſtruum we know.

called the *kidneys*, and conveyed from theſe organs into a reſervoir, which is every where known by the name of *bladder*, where it remains ſome time: it is a kind of ley charged with the acrid matters contained in the animal humours; which if too long retained in the body, would produce diſorder in the functions. Urine is a ſolution of a great number of ſalts, and particularly of extractive matters. When it is recent, it turns the ſyrup of violets neither green nor red: it varies in quantity and quality from ſeveral circumſtances. That of man, which we propoſe to examine in particular, differs from that of quadrupeds. In the other claſſes of animals it exhibits ſtill greater differences. The ſtate of the ſtomach, and that of the humours in particular, produces an infinity of changes, which it will be impoſſible to appreciate till a ſet of experiments be completed, which have been only begun: we ſhall therefore confine ourſelves to human urine in its ſtate of health.

This fluid is diſtinguiſhed by knowing phyſicians into two kinds: the one, called *urine of the drink*, or *crude urine*, flows a little time after repaſt; it is clear, almoſt taſteleſs and inodorous; it contains much fewer principles than the other, which is called *urine of the blood*, or *urine of coction:* this is ſecreted only when digeſtion is finiſhed, and it is ſeparated from the blood by the kidneys; whilſt the former ſeems to filtrate partly from the ſtomach and inteſtines immediately into the bladder through the cellular texture.

The ſtate of the health, and particularly the diſpoſition of the nerves, ſingularly modify the urine. After hyſterical or hypocondriacal paroxyſms, it flows in conſiderable quantity: it has no ſmell, taſte, nor colour. The diſeaſes of the bones and articulations have ſingular influence upon the animal ley. It conveys often a great quantity of matter, apparently earthy, but which appears to be a calcareous phoſphoric ſalt, as we ſhall take more notice afterwards: ſuch is the depoſition of the urine of gouty perſons. Meſſrs Heriſſant and Morand, in partiticular, have obſerved, that when the bones are altered and ſoftened, the patients void a urine which depoſites a great quantity of this matter. It ſeems alſo, that in the ſtate of health, the urine conveys the quantity of this matter, the baſe of the bones, which is ſuperfluous in the nutrition and reparation of theſe organs.

Many aliments are ſuſceptible of communicating certain particular properties to the urine. Turpentine and aſparagus; the former gives it a violet, the ſecond a very fetid, colour. Perſons with weak ſtomachs void urine which retain the ſmell of the aliments taken in. Bread, garlic, onions, broth, and all vegetables, communicate to their urine a ſmell which diſtinguiſhes theſe ſubſtances. We have obſerved that this fluid does not alter the ſyrup of violets when it is freſh; kept ſome time, it turns it green inſtantly. Sometimes urine renders it green the moment it is voided; ſometimes it reddens it, ſince M. Macquer obſerved this property among the melancholici who had made uſe of greens or wine. From all theſe details, we conceive, that urine preſents phenomena to phyſicians, from which they may gain great advantage in practice. We muſt beware of imagining that we can judge, from the inſpection alone of the urine, of a diſeaſe, the ſex of a patient, and the proper remedies, as certain quacks pretend.

Human urine, conſidered anent its chemical properties, is a ſolution of a great number of different ſubſtances. Some are ſalts reſembling the mineral; and which, as M. Macquer thinks, come from the aliments, and have ſuffered no alteration. Others are ſubſtances analogous to the extractive principles of vegetables. Laſtly, there are ſome which appear particular to animals, and even to the urine, or at leaſt which have not been found in the products of the other kingdoms, nor even in the other animal ſubſtances, except urine. After having ſhown the means employed for the extraction of the different ſubſtances from urine, we ſhall give the hi-

hiſtory of theſe matters which are proper to this fluid, and of which we have as yet had no knowledge.

Recent urine, diſtilled in a balneum mariæ, yields a great quantity of phlegm, which is neither acid nor alkaline, but which readily putrefies. As this phlegm contains nothing particular, urine is generally evaporated in an open fire. In proportion as the water, which makes more than ſeven eighths of this animal humour, diſſipates, the urine aſſumes a brown colour; a powdery matter ſeparates, which has an earthy appearance, which has been taken for ſelenite, but which is a true ſalt, of little ſolubility, çompoſed of phoſphoric acid and lime. This ſalt is of the ſame nature as the baſe of the bones; and we ſhall ſpeak of its properties in the hiſtory of theſe organs. When urine has acquired the conſiſtence of a clear ſyrup, it is filtrated and put into a cool place: it there depoſites ſaline cryſtals, which are made up of two particular ſaline ſubſtances, according to the diſcovery of M. Rouelle. Theſe cryſtals are known by the name of *fuſible ſalt*, *native ſalt of urine:* we ſhall examine its properties in a particular article. Theſe cryſtals may be collected at ſeveral times by repeated evaporations and cryſtalliſations. In theſe ſucceſſive evaporations, a certain quantity of marine and febrifugal ſalt cryſtalliſes: when the urine yields no more ſaline matter, it is in the ſtate of a very thick brown fluid, a kind of mother-water, and it holds diſſolved two particular extractive ſubſtances. By evaporation to the conſiſtence of a ſoft extract, and trituring the reſiduum with ſpirit of wine, M. Rouelle diſcovered, that a portion diſſolved in this menſtruum, and that another remained undiſſolved. The firſt has been called a *ſoapy matter*, and the ſecond an *extractive.*

The ſoapy ſubſtance is ſaline and ſuſceptible of cryſtalliſation. It dries only difficulty; and in this ſtate it attracts the air's humidity. It yields to the retort more than half of its weight of volatile alkali, a little oil, and ſome ſal ammoniac: its reſiduum turns the ſyrup of violets green.

The extractive ſubſtance, ſoluble in water and not in ſpirit of wine, dries eaſily in a balneum mariæ, like the extracts of plants: it is black, leſs deliqueſcent than the former: it yields to diſtillation all the products of animal matters. Such are the characteriſtic properties, according to M. Rouelle, that diſtinguiſh theſe two ſubſtances which form the extract of urine. To theſe details let us add, that this celebrated chemiſt extracted from an ounce to more than an ounce and a half of extract from a pint of urine voided after coction, whilſt a like quantity of crude urine gave only one, two, or three gros.

If, inſtead of ſeparating by means of ſpirit of wine this extract of urine into two diſtinct matters, it is fully diſtilled in a naked fire, it furniſhes a great deal of volatile alkali, a very fetid animal oil, ſome ſal ammoniac, and a little phoſphorus. Its coal contains a little common ſalt. This analyſis of urine ſhows, therefore, that this little is formed of a great quantity of water, a little marine ſalt, calcareous phoſphoric ſalt, or the baſe of the bones, a very great quantity of fuſible ſalt, and two particular extractive matters. Before we enter upon the examination of the fuſible ſalt, to which we ſhould direct a particular attention, let us proſecute the action of the different menſtrua upon urine.

Urine, expoſed to the air, is altered ſo much the faſter the hotter the atmoſphere: at firſt depoſitions are formed by ſimple cooling; ſeveral ſaline matters cryſtalliſe at its ſurface and bottom, and frequently a reddiſh ſalt called *gravel.* Nobody has paid more attention to the ſpontaneous alterations of this fluid than M. Hallé my colleague. He diſtinguiſhed, in the decompoſition of urine left to itſelf, ſeveral times, at which the nature of the ſediment, or of the cryſtals depoſited, and likewiſe the changes which they undergo, are evidently different. It is not our object to treat at full length of theſe changes, which will be found accurately deſcribed in an excellent paper written by the phyſician above mentioned, and which will be printed among thoſe of the Royal Society of Medicine. We wiſh to ſhow here only the great alterations which the urine ſuffers. Very ſoon after cooling, its ſmell alters, is exalted, and emits volatile alkali; its colouring part changes, and ſeparates from the reſt of the liquor; at laſt this alkaline odour is diſſipated, and to it ſucceeds another, which is leſs pungent, but more diſagreeable and nauſeous; and the decompoſition being complete terminates. M. Rouelle obſerved, that crude and ſerous urine did not putrefy ſo quickly; that its ſmell, when it altered, differed greatly from that of the urine of coction; and, laſtly, that it was covered with mouldineſs, like the juices of vegetables and the ſolutions of animal gellies. M. Hallé has ſeen certain ſpecimens of urine paſs to the acid before the putrid fermentation. Urine, putrefied for a year and more, ſubjected to evaporation, yields fuſible ſalt juſt like recent urine; but it contains a portion of the acid of this ſalt uncombined; ſo that it raiſes an effervеſcence with the mild alkalis. The putrefaction volatiliſed a part of the volatile alkali. When it is evaporated, the ſalt depoſited upon the ſides of the baſon is acid, and likewiſe effervеſces with the oil of tartar. This obſervation is due to M. Rouelle junior.

Lime and the fixed alkalis inſtantly decompoſe the ſaline principles contained in the urine: it is ſufficient for this purpoſe to pour ſome cauſtic fixed alkali, or to throw ſome quicklime into recent urine, and an inſupportable putrid alkaline odour is evolved. It ſeems that it is from the decompoſition of the fuſible ſalt that theſe ſubſtances produce this odour. M. Bertholet, my colleague, diſcovered, that lime-water furniſhed a precipitate in recent urine, and that phoſphorus might be extracted from this precipitate.

The acids have no action upon recent urine; but they readily deſtroy the putrid ſmell of urine, and that of the depoſitions which it forms in this ſtate.

Urine decompoſes ſeveral mercurial ſolutions. Lemery exhibited, under the name of red precipitate, a magma of a roſy colour, which is formed when ſome nitrous mercurial ſolution is poured into urine. This precipitate is in part formed by the marine acid, and in part by the acid of the fuſible ſalt contained in this fluid. M. Brogniart obſerved, that this preparation ſometimes kindled by friction, and conſumes rapidly upon burning coals. This he attributed to a little phoſphorus.

Such is the preſent ſtate of our knowledge of the chemical properties of urine: there ſtill remains a great deal to be done, to complete what analyſis may diſcover upon this ſubject: it will be neceſſary to examine the different depoſitions obſerved in the urine, which are completely diſtinguiſhed by M. Hallé; the red or tranſparent ſaline concretions which are formed in it; the copious ſediment which the urine lets fall after gouty paroxyſms, and of that of patients attacked with the ſtone.

We are juſt now going to examine, in ſo many particular paragraphs, the ſaline products which are extracted from urine, and with whoſe properties it is neceſſary to be well acquainted.

§ I. *Of the fuſible or native Salt of Urine; or of the phoſphoric ammoniacal Salt.*

THE ſalt which is obtained by the cooling and repoſe of urine, evaporated to the conſiſtence of ſyrup, has been called *fuſible ſalt*, becauſe it fuſes with the fire, as we ſhall preſently ſee, *eſſential ſalt of urine*, and *microcoſmic ſalt*. The name of *phoſphoric ammoniacal ſalt* ſuits it beſt, becauſe it is formed of the particular acid of which phoſphorus is made, and of the volatile alkali.

Several authors, and among the reſt Meſſrs Margraaf, Rouelle, Pott, Schloſſer, and the Duc de Chaulnes, have begun to examine the properties of this ſalt: nevertheleſs, we are not acquainted with them all, as we ſhall ſee from the following obſervations. M. Prouſt has made a precious diſcovery upon the nature of this ſalt, as we ſhall preſently obſerve.

This ſalt, obtained by the proceſs juſt now deſcribed, is not pure; it is rendered impure by an extractive matter, and is frequently mixed with ſome marine ſalt: it is purified by ſolution in diſtilled water and evaporation, or, ſtill better, by allowing this ſolution to evaporate in the open air. The form of its cryſtals has not yet been accurately deſcribed: ſometimes they appear to be octagons, and in other circumſtances it is obtained under the form of flat rhomboids, cut *en biſeau* upon the ſides, and placed obliquely, and as if covering one other. M. Romé de Liſle defines them regular four-ſided figures, formed of four equilateral triangles. M. Rouelle has obſerved, that its form varied egregiouſly. Its taſte is cool and pungent: this ſalt turns the ſyrup of violets green.

When it is put upon burning coals, it bubbles up, emits a volatile alkaline odour, and fuſes. If if is diſtilled in a retort, very penetrating cauſtic volatile alkali is obtained. The reſiduum is a tranſparent glaſs, very fixed and fuſible; which, according to M. Margraaf, is ſoluble in two or three parts of diſtilled water, and preſents the characters of an acid. It has always been ſuppoſed, ſince the experiments of this chemiſt, that this glaſs was pure phoſphoric acid; but M. Prouſt diſcovered in it a particular ſubſtance which is united with this acid, and which covers its properties. We ſhall treat of this ſubſtance in a ſeparate article. It is ſufficient to obſerve here, that the fuſible ſalt ſeemed to be a compound of three bodies.

The fixed alkali, vegetable or mineral, and lime, decompoſe fuſible ſalt, and diſengage its volatile alkali. It decompoſes mercurial marine ſalt, without touching mercurial nitre.

Laſtly, When a mixture of two parts of this ſalt to one of charcoal is ſtrongly heated in a retort, a ſolid product is obtained, combuſtible in the open air, which is known by the name of *phoſphorus*, whoſe properties ſhall be more fully noticed afterwards.

§ 2. *Of the Subſtance diſcovered by Meſſrs Pott, Margraaf, and Prouſt, in the fuſible Salt.* (See Phyſical Journal, vol. xvii. p. 145.)

M. Prouſt, juſt as M. Rouelle, was ſurpriſed at the ſmall quantity of phoſphorus which is obtained from fuſible ſalt treated with charcoal, and at the weak taſte of the vitreous reſiduum of this ſalt, when fuſed and decompoſed by the fire, and ſuſpected that this matter was not the pure phoſphoric acid, and that it contained ſome ſubſtance incapable of forming phoſphorus: conſequently, after having diſtilled a mixture of one part of fuſible ſalt and a half part of charcoal, and having obtained all the phoſphorus, he waſhed the reſiduum of the retort with diſtilled water; he filtrated and evaporated the ley in the open air; he got parallelogram cryſtals, an inch long, laid horizontally upon one another. Their quantity amounted from five to ſix gros in the ounce of phoſphoric glaſs. Meſſrs Pott and Margraaf obtained this ſalt by waſhing the reſiduum of the phoſphorus formed with fuſible ſalt and charcoal; but the former conſidered it as a ſelenitic earth; the latter does not explain its nature, and he ſuſpects that it contains ſtill a little phoſphoric acid. M. Prouſt has paid more attention to it; he has pointed out, by accurate experiments, ſeveral of its properties, and chiefly its ſtate in the fuſible ſalt. From this chemiſt we ſhall borrow the examination of this ſubſtance.

The ſalt, the baſe of the phoſphoric glaſs, cryſtalliſes regularly, as we have ſeen: its taſte is ſlightly alkaline: it turns the ſyrup of violets green.

Expoſed to the fire in a crucible, it bubbles up, loſes the water of its cryſtalliſation, reddens, and fuſes.

The glaſs which it forms is very fluid, and turns opaque upon cooling. Poured upon burning coals, when in fuſion, it gives a green colour to the flame.

Expoſed to the air, it effloreſces.

An ounce of hot water can diſſolve about five gros of this ſalt cryſtalliſed. This ſolution yields cryſtals by cooling.

The ſalt, the baſe of the phoſphoric glaſs, diſſolves the earthy ſubſtances by means of fuſion, and forms with them different glaſſes.

It unites with and ſaturates the alkalis. It is found in human urine, even combined with the mineral alkali; and forms a particular ſalt, to be examined afterwards.

It diſſolves in the mineral acids, and divides their water of ſolution, but ſpirit of wine precipitates it. It yields with the phoſphoric acid, obtained from the phoſphorus, a mixt ſubſtance, ſuſceptible of a vitreous form, and which makes part of the fuſible ſalt of urine, or of phoſphoric ammoniacal ſalt, as we have already ſaid.

It decompoſes nitre and marine ſalt, ſeparating their acids, and uniting with their baſe, as Margraaf has already obſerved.

Laſtly, it does not form phoſphorus when diſtilled with charcoal.

Theſe details demonſtrate, that the ſalt, the baſe of the phoſphoric ſalt, is a particular ſubſtance, owing, according to M. Prouſt, to the work of animaliſation. This chemiſt had obſerved, that this ſubſtance has great analogy with the ſedative ſalt, in its fuſibility, its property of tinging flame green, of decompoſing vitreous and marine ſalts, and of forming with the alkalis particular neutral ſalts. However, it widely differs in the form of its cryſtals, in its alkaline taſte, and property of turning ſyrup of violets green, in its effloreſcence, inſolubility in ſpirit of wine, &c.

As to the nature of this ſingular ſubſtance, the examinamination of which intereſts chemiſts and phyſicians, M. Prouſt ſays, that its anſwer is found; but that it ſo nearly relates to one of the moſt important problems in chemiſtry, that he imagines he ſhould not give the one without the other *.

§ 3. *Of the fuſible Salt with Baſe of Natrum, extracted from Urine.*

M. Margraaf has remarked, that fuſible ammoniacal ſalt of urine was mixed with another ſort of neutral ſalt, which greatly differs from it. M. Haupt has already made known ſeveral of the properties of this ſecond native ſalt of urine, which he has called *mirabile perlatum;* but Meſſ. Rouelle and Prouſt have reſumed the full examination of this ſalt, and to this laſt chemiſt in particular we owe an accurate knowledge of this ſalt.

When fuſible or ammoniacal ſalt is purified, about the end of its cryſtalliſation, and above it, there are formed fine ſaline groups of another nature, whoſe cryſtals are, according to M. Rouelle, flattened four-ſided priſms, irregular, having one of the extremities two-ſided, and compoſed of two rhomboids cut contrary-

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* M. Prouſt ſays, that it is aſtoniſhing M. Margraaf did not diſcover the ſubſtance united with the phoſphoric acid of the fuſible ſalt, and which deprives it of its acid properties in the glaſſy reſiduum of this ſalt, expoſed to the action of heat. However, upon reading Margraaf's Diſſertation, intitled, "Chemical Examination of a Salt of Urine, very remarkable," (firſt volume of his chemical works, Paris 1762, p. 123.) it is found, p. 172, 173, 174. that M. Margraaf, after having diſtilled an ounce of fuſible ſalt, ſeparated from its urinous part, with half an ounce of ſoot, and having extracted a gros of very fine phoſphorus, he waſhed in boiling diſtilled water the caput mortuum of this operation; that this ley, filtrated and evaporated, produced ſeven gros of long cryſtals, which became dry in the air, but which was reduced into a farina by heat. Theſe cryſtals, treated with charcoal, gave no phoſphorus: diſſolved in water, they precipitated metallic ſolutions, decompoſed nitre and marine ſalt in ſmall quantity. Theſe cryſtals appear to be juſt the ſubſtance marked by M. Prouſt.

wiſe, and the other adheres to the baſe. The ſides of the priſm are alternate irregular priſms, and two long pyramids cut *en biſeau*[*]. It is this ſalt which M. Rouelle called *fuſible ſalt with baſe of natrum.* He ſuppoſed that it was formed of phoſphoric acid and mineral alkali. The details to be offered, according to M. Prouſt, will prove that it is not this acid which enters into its compoſition.

Fuſible ſalt with baſe of natrum deſerves this name, becauſe when it is expoſed to the fire in a crucible, it fuſes and yields a glaſs which becomes opaque upon cooling: heated in a retort, it yields only a phlegm, without any mark of its being acid or alkaline.

It diſſolves very well in diſtilled water, and cryſtalliſes by cooling: its ſolution renders the ſyrup of violets green.

The fuſible ſalt with baſe of natrum yields no phoſphorus with charcoal. Meſſrs Rouelle, Margraaf, and Prouſt, have proved this important fact; and it is undoubtedly this phenomenon which has induced this chemiſt to undertake a more complete examination of its nature.

Lime decompoſes this ſalt; and it has more affinity with the ſubſtance, which, as ſhall be more fully explained after, holds here the place of an acid, than with the mineral alkali. If ſome lime-water is poured into a ſolution of this ſalt, a precipitate forms, and the mineral alkali remains pure and cauſtic in ſolution.

The mineral acids, and even diſtilled vinegar, decompoſe it in an inverſe manner. By the action of the acids, M. Prouſt diſcovered the nature of this ſalt. M.

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[*] It were to be wiſhed that all cryſtals were deſcribed with the ſame accuracy with theſe. M. Rome de Liſle has a part of this deſcription in his excellent book, intitled *Chryſtallography.* The knowledge acquired theſe ſome years, leads us to preſume, that the ſecond edition, in which this learned man is now engaged, will contain many cryſtals, whoſe form was unknown at the time of the firſt publication.

Rouelle was of opinion, that the vitriolic and nitrous acids did not act upon this ſalt, becauſe they produced no ſelf-evident change. But M. Prouſt having mixed the vitriolic, nitrous, marine, and acetous acids, with a ſolution of fuſible ſalt with baſe of natrum, has obſerved, that though no precipitate fell in theſe mixtures, the liquors, evaporated and cooled, yielded Glauber's ſalt, cubic nitre, marine ſalt, and terra foliata mineralis; which proves, 1. That this ſalt was decompoſed by the acids; 2. That it contains mineral alkali, as M. Rouelle had already demonſtrated. As to the ſubſtance ſeparated, and which was united with the mineral alkali before, it is clear that it remains in ſolution in the liquors at the ſame time with the new-formed neutral ſalts. M. Prouſt has very fully examined it in the mother-water, which is obtained after the mixture of the vinegar and the cryſtalliſation of the terra foliata mineralis. By pouring upon this mother-water eight or ten times its bulk of hot ſpirit of wine, the laſt portions of the terra foliata diſſolve, and a magma is formed, which is waſhed with new ſpirit of wine, and then diſſolved in diſtilled water. This ſolution of the magma, evaporated in the open air, yields cryſtals like parallelograms, quite ſimilar to thoſe which are extracted from the waſhing of the reſiduum of the phoſphorus made with ammoniacal fuſible ſalt. It is, then, this particular ſubſtance, analagous to the ſedative ſalt, whoſe hiſtory we have given in the preceding article, which ſaturates the mineral alkali in the fuſible ſalt. This important diſcovery explains, why this ſalt gives no phoſphorus: it contains not an atom of phoſphoric acid; it has an analogy with borax, becauſe the ſubſtance which does the part of an acid in it reſembles ſedative ſalt.

Fuſible ſalt with baſe of natrum decompoſes the earthy neutral ſalts, and eſpecially calcareous nitre: it forms a precipitate, which is the combination of lime and the baſe of the phoſphoric glaſs *: the ſupernatant liquor contains a neutral ſalt, formed by the acid of the calcareous ſalt, and the marine alkali of the fuſible ſalt with baſe of natrum.

This ſalt is likewiſe decompoſed by the metallic ſolutions: poured into a ſolution of mercurial nitre, it forms a white precipitate, which, diſtilled in a retort, yields a ſmall quantity of a reddiſh ſublimate, ſome flowing mercury; and at the bottom of the veſſel remains an opaque white maſs, adhering and combined with the glaſs. This is the baſe of the phoſphoric glaſs, ſeparated from the mercury and fuſed. This mercurial ſalt, boiled with a ſolution of ſalt of ſoda, reproduces the fuſible ſalt with baſe of natrum, and leaves the mercury in the ſtate of a red brick-coloured powder †.

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* It muſt be recapitulated, that this new ſubſtance, to which, for want of a better name, we give that of *baſe of phoſphoric glaſs of the fuſible ſalt*; which expreſſes, that it is found always in the glaſs which forms the ammoniacal fuſible ſalt when expoſed to the fire, conſtitutes with the mineral alkali the fuſible ſalt with baſe of natrum, ſo called by M. Rouelle, or the ſal mirabile perlatum of M. Haupt, which we have been examining in this paragraph.

† The microcoſmic ſalt obtained by the firſt cryſtalliſation proves extremely impure, from the adherence of a great deal of the mucilaginous part of the urine; and, what is exceedingly remarkable, we loſe a large proportion of this ſalt in attempting to free it from thoſe impurities by a ſubſequent cryſtalliſation; which does not happen in the depuration of any other ſalt by ſolution and evaporation. M. Baumé firſt diſcovered this ſingular circumſtance by accident, when he had the misfortune to loſe almoſt the whole of the cargo which he had prepared to make Kunckel's phoſphorus with. The Duke de Chaulnes afterwards found, that at leaſt four-fifths of the ſalt were loſt in the experiments which he made to aſcertain the quantity which exhaled during the evaporation of the water; and the Duke, in order to prevent ſo immenſe a waſte, tried ſeveral expedients to ſave the ſalt; and was at length perſuaded that the following method anſwered the purpoſe beſt: He made ſome of the ſalt very hot in a glaſs veſſel, and added one half the weight of warm water. He next poured the whole into a glaſs funnel lined with filtrating paper, and ſet the neck of the funnel into a phial full of boiling water, which ſtood in a ſand-heat to ſupport an equable warmth.

LECTURE LXVII.

§. 4. KUNCKEL'S PHOSPHORUS.

PHOSPHORUS is the moſt combuſtible ſubſtance known. As it was firſt extracted from urine, and as the matter which yields the greateſt quantity of it is

warmth. In this ſituation the ſalt runs all into the phial; which being ſet in a cool place to cryſtalliſe, afforded white and perfectly pure cryſtals, free from every impurity, and with the loſs of no more than one fifth part of the original quantity. The advantage of this proceſs ſeems to conſiſt in making a ſtrong ſolution in boiling water, which yields cryſtals by the mere expoſure to cold, without being ſubjected to the expenditure of ſalt; which always happens in evaporating a weak ſolution down to a ſufficient ſtrength, by the application of heat alone.

M. Margraaf found, that a mixture of this fuſible ſalt with filings of zinc, diſtilled in a retort, yielded a very pure phoſphorus with the aſſiſtance of a much more moderate heat than what is neceſſary with any other inflammable addition. So that zinc ſeems to be the beſt ſubſtance to employ in preparing phoſphorus.

With regard to the volatility of the phoſphoric acid, M. Scheele makes a remark which deſerves ſome attention. He placed ſome of the concrete phoſphoric acid into a glaſs tube, and by approaching the flame of a candle to that ſide of the tube, the phoſphorus ſublimed over to the other; but by the addition of ſome water, the acid became ſo fixed as to bear a red heat without volatiliſing. So that in this caſe two ſubſtances, both volatile when ſeparate, acquire an uncommon degree of fixity by mixture. The fact is indeed analogous to ſome others which occur in chemical reſearches. When the volatile vapours of the nitrous acid, for example, and of the volatile alkali, meet together in the air, they form a ſalt which is no way remarkable for volatility; and in ſome other caſes the compound neither poſſeſſes the volatility nor the ſolubility of the ingredients when ſeparate.

Since the publication of M. Fourcroy's lectures, the preſence of phoſphoric acid in the mineral kingdom has been announced to the world as a diſcovery made by Dr Gahn. The acid is mineraliſed with lead, from which the phoſphorus is obtained pure, by diſſolving the mineral ſalt completely in nitrous acid; then precipitating the whole lead by the addition of the vitriolic, pouring off the ſupernatural liquor, which conſiſts of phoſphoric and nitrous acids mixed together, and afterwards expelling the nitrous acid by heat when the phoſphoric acid remains behind. This is the very ſame proceſs which was originally employed to ſeparate the phoſphoric acid from animal bones, and is in every reſpect perfectly juſt.

the ammoniacal fuſible ſalt, which we have juſt now been examining, it is our opinion that the hiſtory of this inflammable ſubſtance ſhould be inſerted here.

The diſcovery of phoſphorus is owing to an alchemiſt called *Brandt*, a citizen of Hamburg, who diſcovered it in the year 1677. Kunckel aſſociated with one called *Kraaft*, in order to gain the ſecret; but Kraaft not communicating it to him, Kunckel reſolved to ſearch for it; and after having undertaken an inveſtigation of urine, from which he knew it was extracted, he ſucceeded in making phoſphorus, of which he ought to be conſidered as the true inventor. Some aſcribe the honour of this diſcovery alſo to Boyle, who indeed depoſited a ſmall quantity of it, 1680, in the hands of the ſecretary of the Royal Society of London: but Stahl ſays, that Kraaft told him, that he communicated the proceſs to Boyle. This laſt phyſician gave his proceſs to a German called *Godfreid Hankwitz*, who had an elegant laboratory in London, and was the only perſon who made phoſphorus, and who ſold it to all the philoſophers in Europe. Although, from the year 1680 to the commencement of the preſent century, there appeared a great number of receipts for the preparation of phoſphorus; and among others, thoſe of Boyle, Kraaft, Brandt, Homberg, Teichmeyer, Frederic Hoffman, Niewentyt, and Wedelius; no chemiſts as yet prepared it; and this preparation was a real ſecret, when, in the year 1737, a foreigner offered at Paris a method of preparing phoſphorus with ſucceſs. The academy nominated four chemiſts, Meſſrs Hellot, Dufay, Geoffroy, and Duhamel, to inveſtigate this operation in the laboratory of the royal gardens: this proceſs ſucceeded very well. The miniſter recompenſed the foreigner; and M. Hellot deſcribed it with accuracy, in a paper inſerted among thoſe of the academy *anno* 1737. This operation conſiſts in evaporating five or ſix quarts of urine, till it be reduced to a grumous, conſiſtent, black, and ſhining matter; in calcining this reſiduum in an iron laddle, whoſe bottom is made red-hot, till it no longer fumes, and till it has the ſmell of flowers of peaches; in waſhing this calcined matter with the double, or leſs, of hot water; and in drying it after having decanted off the water. Three pounds of this matter are mixed with a pound and a half of groſs ſand or grated freeſtone, and four or five ounces of powder of charcoal of beech: this mixture is moiſtened with half a pound of water, and introduced into a Heſſian retort. We eſſay the matter by making it red in a crucible; when it emits a violet flame and a garlic ſmell, it will yield phoſphorus. The retort is placed in a furnace made fit for the purpoſe; and a large receiver, filled two-thirds with water, is adapted to it. This receiver muſt be pierced with a ſmall hole; and M. Hellot conſidered this as one of the moſt neceſſary ſteps to the ſucceſs of the operation. Three or four days after the apparatus has been ſet in order, the fire is applied with great moderation, in order to complete the exſiccation of the furnace and the lutes; it is gradually augmented to the greateſt force of heat, and in this ſtate ſupported for five or ſix hours. The phoſphorus diſtils only at the end of four hours after the commencement of the operation, which continues in the whole twenty-four; previouſly, a great quantity of concrete volatile ſalt riſes, which diſſolves in part in the water of the balloon. The volatile or aëriform phoſphorus paſſes over firſt in luminous vapours; the real phoſphorus next flows like an oil or fuſed wax. When no more paſſes over, the apparatus is left two days to cool; it is unluted, and ſome water added into the receiver, to detach the phoſphorus adhering to its ſides: it is made to melt in boiling water, and cut into ſmall pieces, which are introduced into a tapering glaſs tube, and then immerſed into boiling water. The phoſphorus fuſes, is purified, and becomes tranſparent, by the ſeparation of a black matter which is raiſed above it: then it is cooled in cold water, where it congeals; it is taken out of the tube by being puſhed from the ſmaller through the longer end. Such is a ſhort view of M. Hellot's deſcription; the length of the operation prevented chemiſts from repeating it, if we except M. Rouelle, who, in his chemical courſes, practiſed it with ſucceſs ſeveral times.

In the year 1743, M. Margraaf, in the Memoirs of the Berlin Academy, publiſhed a new method of making a great quantity of phoſphorus, with leſs trouble than had been done before. According to his proceſs, ſome plumbum corneum, the reſiduum of the diſtillation of four pounds of minium and two pounds of ſal ammoniac, is mixed with ten pounds of the extract of urine, in the conſiſtence of honey. Half a pound of powdered charcoal is added: the mixture is dried in an iron veſſel till it be reduced to a black powder; this is diſtilled in a retort, in order to extract by a well-regulated fire the volatile alkali, fetid oil, and ſal ammoniac. The fire muſt not be made more violent than ſo as to make the bottom of the retort moderately red. The black and friable reſiduum of this operation is the matter from which the phoſphorus is extracted: it is aſſayed by laying a little of it on burning coals; if it emits a garlic ſmell and a blue phoſphoric flame, it is properly prepared. With this we fill three-fourths of a Heſſian or Picardy ſtone retort, well covered with a lute: this veſſel is placed in a reverberatory furnace, terminated by the head of a wind-furnace, and by an iron pipe ſix or eight feet high; a middle-ſized receiver, pierced with a ſmall hole, and half filled with water, is adapted to the retort; the joinings are ſecured with fat lute, covered with pieces of cloth lined with whites of eggs and lime: a brick-wall is raiſed between the furnace and receiver: the apparatus is allowed a day or two to dry; then the diſtillation commences by a gradual fire. This operation continues from ſix, eight, or nine hours, according to the quantity of matter employed. This phoſphorus is rectified by diſtilling it with a very gentle fire in a glaſs retort, with a recipient half full of water. Almoſt all the chemiſts have repeated M. Margraaf's proceſs with ſucceſs; and this alone was in uſe, till, ſeveral years ago, a method was diſcovered of ſeparating the phoſphoric acid from bones, as we ſhall remark upon ſpeaking of theſe organs.

It is evident that M. Margraaf's proceſs differs from that of M. Hellot only in the addition of plumbum corneum, the utility of which is not yet properly known, and in the diviſion of the operation into two. But what is of greateſt value in the labours of this celebrated Berlin chemiſt is, he has fully determined what is the ſubſtance contained in the urine which ſerves for the formation of the phoſphorus. By diſtilling a mixture of ammoniacal fuſible ſalt and charcoal, he obtained a very fine phoſphorus; and he obſerved, that the urine from whence this ſalt was got, yields almoſt no more of this combuſtible ſubſtance. It is therefore a conſtituent part of the ammoniacal fuſible ſalt which contributes to the formation of phoſphorus; and this ſubſtance is eaſily obtained by diſtilling two parts of the glaſs obtained from the ſalt decompoſed in a retort or crucible with one part of powdered charcoal. This operation requires much leſs time and much leſs fire than the methods hitherto deſcribed; ſince, according to M. Prouſt, the phoſphorus may come over in a quarter of an hour. It is without contradiction the beſt proceſs which we can adopt in the preparing of the phoſphorus of urine; but there are ſeveral obſervations to be made upon this point. 1. The vitreous reſiduum ariſing from the decompoſition by the fire of the fuſible ammoniacal ſalt, not being pure phoſphoric acid, but this combined with the ſubſtance diſcovered by M. Prouſt, and having in it only this acid which is capable of forming phoſphorus along with charcoal; only very little phoſphorus is obtained by employing this reſiduum, as an ounce yields only a gros, and often leſs. 2. When the fuſible ſalt is prepared in great quantity by evaporation and cooling, it is found to be mixed with a good part of fuſible ſalt with baſe of natrum; which, according to M. Prouſt's diſcovery, contains no phoſphoric acid, and cannot yield phoſphorus. It is conceivable then, from theſe two obſervations, why ſo little of this combuſtible body is obtained by the diſtillation of the fuſible ammoniacal ſalt with charcoal.

Phoſphorus obtained by all the methods now deſcribed is always the ſame. When it is very pure, it is tranſparent, of a conſiſtence ſimilar to that of wax; it cryſtalliſes in brilliant laminæ, as if micaceous, by cooling; it fuſes in warm water long before this fluid boils; it is very volatile, and turns into a thick fluid by means of heat: if it is in contact with the air, it emits a fume from the whole of its ſurface; this vapour, which diſcovers a ſtrong ſmell of garlic, ſeems white in the daytime, and very luminous in a dark place. This is then the ſlow inflammation of phoſphorus; indeed, if it is left any time thus expoſed to the air, it conſumes gradually, and leaves for a reſiduum a particular acid, whoſe properties we ſhall examine more fully after this. This ſlow combuſtion never goes on, except when the phoſphorus is in free contact with air; it even requires, in order to be very luminous, a heat from twelve to fifteen degrees, although it takes effect at an inferior temperature. This inflammation is produced without heat, and it kindles no combuſtible body. But when phoſphorus ſuffers a dry heat of twenty-four degrees, it kindles with decrepitation; it burns rapidly with a white flame mixed with yellow and green, very bright, and it deſtroys with great readineſs all the combuſtible bodies which it touches. The vapour which is then exhaled from it is very copious, white, and very luminous in the dark. It leaves a reſiduum, differing in the one and the other of theſe combuſtions. The firſt yields a liquor more than double the weight of the phoſphorus employed, which is called *phoſphoric acid*. The ſecond exhibits a thick matter, of a reddiſh white, which emits white vapours till it has attracted enough of the air's humidity to make it fluid; then it reſembles the acid and fluid reſiduum of the firſt combuſtion or ſlow inflammation. However, theſe acids preſent ſome differences in their combinations, as M. Margraaf has obſerved, and as M. Sage has ſhown in the Memoirs of the Academy 1777. We ſhall fully deſcribe theſe differences when we come to treat of the phoſphoric acid.

The combuſtion of phoſphorus was conſidered by Stahl as the diſengagement of phlogiſton, which he imagined was combined with the marine acid * in this combuſtible body. M. Lavoiſier, with a view of aſcertaining what paſſes in this combuſtion, kindled, by means of a burning-glaſs, ſome phoſphorus under a glaſs-veſſel full of mercury. He has obſerved, that only a given quantity can burn in a determinate portion of air, and that this quantity amounts to a grain in ſixteen or eighteen cubic inches of air: that after this combuſtion the phoſphorus is extinguiſhed, and that the air can no longer ſerve to ſupport a new inflammation; that the volume of the air diminiſhes; and that the phoſphorus is diſſipated in white ſnowy flocci, which attach themſelves to the ſides of the veſſel. Theſe flocci have twice and a half the weight of the phoſphorus employed; and this increaſe of weight correſponds exactly with that which the air loſt, and depends ſolely upon the abſorption of the pure air by the phoſphorus. In fact, the white tufts are the concrete phoſphoric acid, and formed by the combination of the phoſphoric acid with the pure air contained in the atmoſpheric air, which has ſerved for the combuſtion of this inflammable ſubſtance. The theory here is the ſame as that applied to ſulphur; and it

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* Stahl aſſerts in ſeveral of his works, that by combining marine acid with phlogiſton, phoſphorus may be formed. M. Margraaf conſequently began ſome experiments with this view, by treating different combinations of marine acid with combuſtible ſubſtances; but he never produced an atom of phoſphorus. He has alſo demonſtrated, that the acid, the reſiduum of this combuſtible body, widely differs from muriatic acid; and all chemiſts are now convinced of this fact. We cannot ſay what ſhould have led into ſuch a miſtake ſo able and ſo creditable a perſon as Stahl.

it would be uſeleſs to add what we have ſaid upon this ſubject in the mineral kingdom.

Phoſphorus liquifies in hot water. Although it is inſoluble in this fluid, it is, however, a little altered. It loſes its tranſparency; it turns yellow, and is covered with an effloreſcence or coloured powder. The water becomes acid; it appears luminous when ſhaken in the dark: phoſphorus then is ſlowly decompoſed in it.

The action of a great number of bodies upon phoſphorus is unknown. The knowledge we have of this ſubject is almoſt all owing to M. Margraaf, and from him we ſhall make the following brief obſervations.

Vitriolic acid diſtilled in a retort with phoſphorus, decompoſes it almoſt entirely, but without inflammation. The nitrous acid attacks it with violence, and ſuddenly inflames it. The marine acid makes no alteration.

Sulphur and phoſphorus combine by fuſion and diſtillation: a ſolid compound reſults of an hepatic ſmell, which burns with a yellow flame, and ſwells in water, to which it communicates acidity and the ſmell of liver of ſulphur, properties which certainly ſhow a particular reaction between theſe two bodies.

Phoſphorus does not unite ſo well with the metals as ſulphur does; although a very great number of analogous properties ſubſiſts between it and this laſt. M. Margraaf tried to make theſe combinations, by diſtilling each metallic ſubſtance with two parts of phoſphorus. Only arſenic, zinc, and copper, preſent particular phenomena: all the reſt of the metals were not altered by phoſphorus; and this matter was in part conſumed, and paſſed into the receiver without ſuffering any remarkable change. Phoſphorus, ſublimed with arſenic, preſented to him a matter of a beautiful red colour, ſimilar to realgar. Zinc, diſtilled ſucceſſively with this ſubſtance, yielded yellow, pointed, and very light flowers. Theſe flowers, expoſed to the fire under a red muffle, kindled, and yielded a tranſparent glaſs ſimilar to that of borax.

Copper, treated in the ſame way with phoſphorus, loſt its brilliancy, and became very compact; it had acquired ten grains upon half a gros, and it kindled upon the approach of flame.

Phoſphorus diſſolves in all the oils, and renders them luminous. M. Spielman ſays, that he diſſolved it in ſpirit of wine, and that this ſolution yielded ſparks when poured into water.

Phoſphorus is not yet of any uſe either in medicine or in the arts. Meſſrs Menzius, Morgenſtern, Hartman, &c. ſay, that they have experienced good effects from it in malignant and bilious fevers, in debilities of the ſyſtem, miliary fever. Others have recommended it in the meaſles, peripneumony, rheumatiſm, epilepſy, &c. But although ſeveral diſſertations upon the virtues of phoſphorus uſed internally have appeared already in Germany, we cannot as yet ſay any thing with certainty upon this ſubject.

§ 5. *Of the Acid of Phoſphorus.*

The acid of phoſphorus has been ſo named, becauſe it was thought to exiſt already formed in phoſphorus, from which we obtain it by combuſtion: but M. Lavoiſier has proved, that this ſalt is a combination of phoſphorus with pure air.

In general there are two proceſſes for obtaining it. The one conſiſts in burning phoſphorus with rapidity, and by applying a briſk heat; the other in allowing it to conſume and burn ſlowly by expoſing it to the air. The firſt yields a concrete acid, which is twice and a half the weight of the phoſphorus, and powerfully attracts humidity from the air; but it always retains ſome pieces of phoſphorus undecompoſed. The other method, after ſome time, affords a fluid without ſmell, of an acid taſte, and not corroſive; which differs from the former obtained by deflagration in this, that with alkalis it is ſuſceptible, according to M. Sage, of forming neutral ſalts different from thoſe formed by the other acid. The differences, however, are but ſlight, at leaſt thoſe mentioned by M. Sage: and with ſtrictneſs we may look upon them as the ſame acids, notwithſtanding the different modifications of their properties.

In order to obtain the phoſphoric acid by deflagration, we muſt make uſe of Lavoiſier's proceſs; which conſiſts in ſetting fire to the phoſphorus by means of a lens, under a large glaſs bell immerſed in mercury, a little water being applied round the outſide of the bell where it ſinks in the mercury. This combuſtion is repeated according to the quantity of acid which we wiſh to have.

The phoſphoric acid *per deliquium*, or ſlow combuſtion, is obtained after *M. Sage's method*, by putting ſticks of phoſphorus upon the ſides of a glaſs funnel, the neck of which is inſerted into a bottle and baſe covered with a head; a glaſs tube being affixed to the neck of the funnel to retain the phoſphorus, and to give vent to the air in the bottle, which is diſplaced by the acid. After ſome time, for every ounce of the phoſphorus we obtain three of the acid, which runs into water deſignedly put into the bottle.

The phoſphoric acid obtained in this way is a tranſparent fluid very pure, has a ſour taſte, and reddens the ſyrup of violets, but is without ſmell. If we expoſe it to the fire in a retort, a pure phlegm comes over; the acid becomes concentrated, and weighs heavier than the vitriolic. By little and little it turns tenacious, and becomes white and ſoft like an extract. Laſtly, urged with a violent fire, it runs into a tranſparent glaſs. This glaſs differs from that of fuſible ſalt in this, that it has a ſour taſte, and attracts humidity from the air. Theſe properties are the conſequence of its being a pure acid, whilſt that of fuſible ſalt is combined with the ſubſtance diſcovered by M. Prouſt; of which we have treated in a particular article.

If we burn the phoſphoric acid *per deliquium* in an

open

open veſſel, it exhibits from time to time ſmall flames, owing undoubtedly to a little phoſphorus remaining, which has not been entirely conſumed, accompanied with a ſmell of garlic : the remainder becomes concentrated, dries, and at laſt fuſes in the ſame manner as when treated in a cloſe veſſel.

The concentrated vitriolic acid very quickly attracts humidity from the air. Its union with water is attended with heat. It combines with a great number of ſubſtances, as we ſhall ſoon ſee, and preſents particular phenomena in its combination. Meſſrs Margraaf and Lavoiſier have examined it when combined with alkaline and metallic ſubſtances ; and upon their inquiries we ſhall found the hiſtory of the different phoſphoric neutral ſalts.

The phoſphoric acid ſeems to act on quartz and glaſs ; but we have not yet examined exactly the nature of the alteration which it occaſions on them.

It diſſoves mild magneſia with efferveſcence : The ſalt reſulting from this combination poſſeſſes but a ſmall degree of ſolubility. A ſtrong ſolution of it, ſet by for twenty-four hours, affords cryſtals like ſmall needles, flattened very thin, ſeveral lines long, and cut obliquely at both ends. They are reduced into powder by expoſure to a gentle heat. The vitriolic acid decompoſes this ſalt, according to M. Lavoiſier, who has the merit of this detail, as well as of ſeveral of the following details upon phoſphoric alkaline ſalts.

This acid, mixed with lime-water, precipitates along with the lime in form of a very inſoluble ſalt, which makes no efferveſcence with acids, and has always the acid to exceſs. It reddens blue paper ; the mineral acids, and even the cauſtic fixed alkali, decompoſe it. From the ſolution of ſilver in aquafortis, it gives a precipitate of the colour of dregs of wine ; and from that of mercury, in the ſame acid, a white powdery precipitate.

The phoſphoric acid, ſaturated with fixed alkali, forms a very ſoluble ſalt. Its ſolution evaporated, and ſet in the cold, affords cryſtals like four-ſided priſms, terminated likewiſe by pyramids with four ſurfaces, correſponding with thoſe of the priſms. This phoſphoric tartar is acid. It diſſolves much better in warm than in cold water. It puffs up when laid on burning coals: it fuſes with great difficulty; and when once fuſed, it loſes its ſaline taſte. It throws down a white precipitate from ſilver in nitrous acid, and a whitiſh yellow from the ſolution of mercury.

The mineral alkali united with the phoſphoric acid, affords a ſalt of an agreeable taſte, analagous to that of marine ſalt. This ſalt does not cryſtalliſe at all. By evaporation it becomes like a gummy matter, ropy like turpentine, and deliqueſcent.

The ſalt which we mean here, M. Lavoiſier prepared with the acid obtained by the deflagration of phoſphorus; but M. Sage has aſſerted, that the acid *per deliquium* afforded cryſtals not deliqueſcent.

The ammoniacal phoſphoric ſalt, formed by the union of this acid obtained by deflagration and the volatile alkali, is more ſoluble in warm than in cold water. In cold, it affords cryſtals, which, according to M. Lavoiſier, have ſome reſemblance to thoſe of alum. This ſalt ought to differ from that formed by the evaporation of urine, in this reſpect, that the fuſible ſalt contains an acid already neutraliſed, by the ſubſtance explained in § 2. and is compoſed of three different ingredients; whilſt the true ammoniacal phoſphoric ſalt, or the phoſphoric acid united to the volatile alkali, contains only two.

The phoſphoric acid decompoſes nitre and ſea-ſalt, and diſengages their acids by diſtillation, not on account of its greater affinity with their baſes, but on account of its fixity.

The fluid phoſphoric acid acts on a ſmall number of metallic ſubſtances only. It diſſolves zinc, iron, and copper well. Their ſolutions evaporated do not cryſtalliſe,

ſtalliſe, that of iron excepted, which ſeems ſuſceptible of cryſtalliſation. The ſolutions of zinc and copper become ductile and ſoft maſſes, reſembling extracts. If we urge them with heat, they throw out ſparks, and appear formed of true phoſphorus. M. Margraaf and the academicians of Dijon have examined in detail the action of this acid on the metals and ſemimetals. It precipitates ſome metallic ſolutions likewiſe; ſuch as that of mercury in the nitrous acid; the precipitate of which is white, and is rediſſolved when the mixture is expoſed to cold.

The ſolution of lead in the ſame acid is in like manner precipitated by the phoſphoric acid. It acts on the oils; it exalts their flavour, and imparts to thoſe that have none a ſweet odour like that of ether. It thickens others. When diſtilled in its ſtate of dryneſs with charcoal, it forms phoſphorus. Heated in a retort with ſpirit of wine, it afforded to the academicians of Dijon a very acid liquor, which burnt with a little ſmoke, and exhibited ſeveral of the properties of ether. This experiment ſhows that the phoſphoric acid had acquired volatility, ſince the product was acid. Laſtly, it diſſolves the ſubſtance remaining after the formation of phoſphorus from the fuſible ſalt, and forms by fuſion with it a hard glaſs, inſipid, inſoluble, not deliqueſcent; in a word, the ſame reſult as that left after the fuſible ſalt has been urged by fire. According to M. Prouſt, it can even take up an exceſs of this ſubſtance.

This acid is as yet of no uſe. In the mean time, it merits all the attention of phyſicians, ſince it makes part of ſeveral animal ſubſtances, and is ſecreted in greater or ſmaller quantities by the urinary veſſels, in the different diſeaſes which attack the bones, articulations, &c.

It is proper to mention here what Margraaf imagines, that this acid can very well exiſt in the aliment, and paſs from vegetables to animals; ſince he ſays he ob-

obtained phoſphorus by heating charcoal of muſtard, wheat, &c. with a great fire. Some chemiſts even believe the phoſphoric acid to exiſt in minerals; but ſuch conjectures are not to be regarded, except ſo far as they are demonſtrated by accurate experiments.

§ 6. *Of the urinary Calculi.*

The calculi or ſtones which form in the human bladder, conſtitute one of the moſt terrible diſeaſes which man has to encounter. Phyſicians have more knowledge of the origin and formation of theſe concretions than chemiſts have of their nature. There are ſome analyſes in the retort, which indicate that the calculi yield an alkaline phlegm, a little oil, and much concrete volatile alkali: it is known, that in general the acids diſſolve them, and that the alkalis have alſo a remarkable action upon theſe ſubſtances; but they have not been completely enough examined to form an accurate judgment of their nature. This examination will undoubtedly furniſh intereſting facts; particularly at this time, when ſo valuable knowledge is acquired of the nature of the bones, with the baſe of which the calculous matter has been long known to have the greateſt analogy. It is very probable, that the ſame ſalt as in the bones will be found in the calculi of the bladder; and the analyſis of the bones may, to a certain degree, be referred to that of theſe concretions.

LECTURE LXVIII.

Of the INSENSIBLE PERSPIRATION *and* SWEAT.

PHYSICIANS have diſcovered a great analogy between the urine and the fluid which iſſues through the ſkin; they know that theſe ſecretions ſupply one another's place in different circumſtances, and they are naturally led to conſider the vapoury fluid of tranſpiration as of the ſame nature with urine. However, it has been hitherto impoſſible to collect a ſufficiently great quantity of this humour for chemical inveſtigation. The practice of medicine has ſhown, that its qualities vary; that its ſmell is inſipid, aromatic, alkaline, or ſour; that its conſiſtence is ſometimes glutinous, thick, tenacious, and that it leaves a reſiduum upon the ſkin; that it frequently tinges linen yellow and of different ſhades; laſtly, M. le Count de Milly has obſerved, that through the pores of the ſkin a gaſeous fluid iſſues, which he took to be aërial acid, or fixed air. Therefore a great number of experiments remains to be made, which particular circumſtances alone will be able to give phyſicians the opportunity of undertaking and purſuing.

Of the ſolid Excrements of Animals.

THE aliments with which animals are nouriſhed contain a great quantity of matter which is incapable of affording them any ſupport, and which is thrown out of the inteſtines in a ſolid form. The excrements are coloured by a portion of bile which they carry along with them; their fetid ſmell is owing to the commencement of putrefaction which they undergo in the long tract thro' which they paſs in the inteſtines. Homberg is the only chemiſt who has examined theſe matters. He has obſerved, that the phlegm furniſhed from the excrements, diſtilled in a balneum mariæ, was of a diſagreeable ſmell: he extracted from it, by waſhing and evaporation, a ſalt, which fuſes like nitre, and inflames in cloſe veſſels. This matter, diſtilled in a retort, yielded him the ſame products with the other animal-matters. Putrefied excrements furniſhed him an oil without colour or ſmell, which did not fix mercury into ſilver, as he had been told.

It muſt be obſerved, that the feculent matter which Homberg examined was furniſhed from men who were nouriſhed with bread of Goneſſe and Champagne wine.

No doubt, the kind of nouriſhment muſt influence the fæces, as they are only the reſiduum of the aliments.

Of the ſoft and white Parts of Animals.

ALTHOUGH the analyſis of the ſoft parts of animals be leſs advanced than that of their fluids, we are now coming to perceive the different matters of which they are compoſed. We mean to talk here only of the ſoft and white parts, becauſe the muſcles and the bones will be treated of in a ſeparate article.

All the ſoft and white parts, ſuch as the membranes and ligaments, the tendons and cartilages, in general contain a mucous ſubſtance, very ſoluble in water, and inſoluble in ſpirit of wine, which is known by the name of *gelly*. This gelly is extracted by boiling theſe animal parts in water, and by evaporating this decoction to a ſolid tremulous maſs, and by cooling. If it is more ſtrongly evaporated, a dry ſubſtance is obtained, which is brittle and tranſparent, and known by the name of *glue*. This laſt is prepared with all the white parts of animals. With the ſkin, cartilages, oxen feet, the ſtrong Engliſh, Flemiſh, and Dutch glue is prepared; with ſerpent's ſkin the glue for gilding is made; with the parings of gloves and parchment a glue is made, which is uſed by the painters, &c.; and, laſtly, there are almoſt no animals whoſe tendons, cartilages, nerves, and particularly ſkin, cannot ſerve for the preparation of theſe kinds of glue. It muſt, however, be obſerved upon this ſubject, that glues differ from one another in conſiſtence, colour, taſte, ſmell, and ſolubility. Some ſoften very well in cold water; others diſſolve only in boiling water. The beſt of theſe ſubſtances ought to be tranſparent, of a yellow colour inclining to brown, without ſmell and taſte; it ought to diſſolve entirely in water, and form a viſcous uniform fluid, which dries, preſerving a tenacity and tranſparency equal throughout.

Animal gelly differs from *glue*, properly ſo called, only in its having leſs viſcoſity and conſiſtence.

The firſt is extracted eſpecially from the white and ſoft parts of young animals: it is found alſo in their fleſh or muſcles, in their ſkin and bones. Glue is obtained only from more aged animals, whoſe fibre is ſtronger and more dry. However it be, as theſe two ſubſtances preſent the ſame chemical phenomena, we ſhall for the example which we are going to take, pitch upon the gelly which is yielded by the cartilages or membranes of a calf.

This matter has almoſt no ſmell in its natural ſtate. Diſtilled in a balneum mariæ, it yields an inſipid phlegm without ſmell, and ſuſceptible of putrefying. In proportion as it loſes its water, it acquires the conſiſtence of glue; and when fully dried, it reſembles horn. Expoſed to a ſtronger fire and air, it ſwells, bubbles up, and liquefies; it blackens, and emits a copious fume of a fetid ſmell; it kindles with a violent heat only, and ſtill difficultly. Diſtilled in a retort, it yields an alkaline phlegm, an empyreumatic oil, and concrete volatile alkali, or mild ſal ammoniac. It leaves a large coal very difficult of incineration, and containing only very little fixed alkali and febrifugal or marine ſalt.

The gelly, expoſed to a moiſt and hot air, paſſes very ſoon to acidity, and very ſoon after that putrefies.

Water diſſolves it in all proportions. The acids, and particularly the alkalis, diſſolve it. The oils and ſpirit of wine have no action upon it. The moſt part of theſe properties approximate the gelly to the inſipid vegetable juices, if we except that of giving volatile alkali in its analyſis. But might not this laſt property be attributed to a portion of lymphatic matter, which water extracts at the ſame time with the gelatinous ſubſtance, particularly when the gellies or glues have been prepared by a ſtrong and long decoction?

Of the Fleſh or Muſcles of Animals.

THE muſcles of animals, chemically conſidered, are formed of a parenchymatous and cellular ſubſtance, in which different humours are contained, partly concrete, and partly fluid. Theſe humours are compoſed, 1. Of a red and white lymph. 2. Of a gelatinous ſubſtance. 3. Of a ſweet oil of the nature of fat. 4. Of a particular extractive ſubſtance. Laſtly, of a ſaline matter, whoſe nature is ſtill little known. As the analyſis of entire fleſh, which yields in a balneum mariæ a vapid water, in the retort an alkaline phlegm, an empyreumatic oil, and concrete volatile alkali, which leaves a coal from which a little fixed alkali and febrifugal or marine ſalt is extracted by incineration, affords no accurate proof of the nature of theſe different principles, recourſe muſt be had to means by which theſe ſubſtances may be extracted without altering them, and which allow their properties to be examined apart.

In order to obtain and ſeparate theſe different ſubſtances inveſtigated by M. Thouvenel *, different methods may be employed. This phyſician uſed expreſſion in order to obtain the fluids in ſpongy muſcles; the action of heat to coagulate the lymph, and to obtain the ſalt by evaporation; water to diſſolve the gelatinous mucilage; ſalt, and extract, and ſpirit of wine, to carry off theſe two laſt principles without the gelly. It is in ge-

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* In this place the medico-chemical paper of this phyſician ſhould be read, which treats of the virtues and principles of the animal medicated ſubſtances, which won the prize of the Bourdeaux Academy 1778. M. Thouvenel has paid great attention to the analyſis of animal matters: to him we owe ſeveral diſcoveries; but we would do well to keep in ſight, that as his intention was only to appreciate, by chemical analyſis and obſervations the medicinal properties of theſe maters; what he has ſaid upon their nature is not ſo full, and perhaps not ſo clear, eſpecially with regard to the fleſh of animals, as could have been wiſhed in inquiries of philoſophical chemiſtry. He himſelf has made the ſame reflection in his above-mentioned work.

general very difficult to ſeparate completely theſe different matters, becauſe all are ſoluble in water, and ſpirit of wine diſſolves the ſoapy extract at the ſame time and a part of the ſalt. The proceſs which ſucceeds beſt, appears to be that which conſiſts, firſt in waſhing the fleſh in cold water, which carries off the colouring lymph with a part of the ſalt; next, in digeſting the reſiduum of this waſhing in ſpirit of wine, which diſſolves the extractive part and a portion of the ſalt; laſtly, in boiling in water the fleſh treated by theſe two proceſſes. This fluid diſſolves the gelatinous part by ebullition, and it carries off alſo the portions of extract and ſalt which have eſcaped the action of the firſt menſtrua.

By ſlowly evaporating the firſt water employed cold, the lymph coagulates; it is ſeparated by filtration; and the ſlow evaporation of the filtrated liquor furniſhes the ſaline matter. Upon evaporating likewiſe the ſpirit of wine, the colouring extractive matter is obtained: and, laſtly, decoction furniſhes the gelly and fat oil, which ſwims upon the ſurface, and fixes by cooling. After the extraction of theſe different ſubſtances, no more remains than the fibrous texture; it is white, inſipid, ſoluble in water; it contracts when burning; it yields a great deal of volatile alkali and very fetid oil to the retort; laſtly, it has all the characters of the fibrous part of the blood. Hence it ſeems to be demonſtrated, that the muſcular organ is the reſervoir in which the action of life depoſites the fibrous matter, which becomes concrete by repoſe, and which appears to be the focus or the baſe of the animal property called *irritability* by phyſiologiſts.

No more remains for us in knowing completely the fleſh of animals, but to examine the properties of each of the ſubſtances of which it is compoſed.

The lymph, the gelly, and the fat part, are already known to us: the firſt perfectly reſembles that of the blood. We muſt obſerve, that it is it which upon coagulation by the heat of water in which the meat is boiled to make broth, produces the ſcum, which is taken off with care. This ſcum is of a dirty brown red, becauſe the red lymph is altered by the boiling heat. The gelly, extracted from the fleſh, generally converts into a tremulous maſs the broths prepared with the fleſh of young animals, which contains much more of it than that of old ones; it is entirely ſimilar to that which conſtitutes the white and ſoft parts of animals, whoſe properties we have deſcribed in the preceding article The fat matter which forms the flat round drops which ſwims upon the ſurface of broth, and which becomes ſolid by cooling, preſents all the characters of fat We have then only to examine the extractive matter and the ſalt which is obtained in the analyſis of the muſcles.

The ſubſtance, which M. Thouvenel calls *mucous extractive*, is ſoluble in water and ſpirit of wine; it has a remarkable taſte, whilſt the gelly has none When it is very concentrated, it forms an acrid and bitter matter; it has a particular aromatic ſmell, which heat evolves; it is it which colours the broth, and which gives it the agreeable taſte and ſmell, which is peculiar to it. When it is evaporated too much, or when a great quantity of meat is put in to that of the water, the broth is more or leſs coloured, and more or leſs acrid. Laſtly, the action of heat evolves and extracts the taſte of this extractive matter almoſt to the point of communicating the taſte of ſugar or caramel, as is obſerved at the ſurface of roaſted meat. If we examine farther the properties of this extractive ſubſtance evaporated to a dry conſiſtence, it is obſerved, that its taſte is acrid, bitter, and ſalt; when put upon a burning coal, it bubbles up and liquefies, exhaling a pungent acid ſmell ſimilar to that of burnt ſugar; expoſed to the air, it attracts its humidity, and forms a ſaline effloreſcence at its ſurface; it turns ſour and putrid in a warm air, when it is diluted in a certain quantity of water; and, laſtly, it is ſoluble in ſpirit of wine. All theſe characters approximate this ſubſtance to the ſoapy extracts, and to the ſaccharine matter of vegetables.

As to the ſalt which cryſtalliſes in the ſlow evaporation of the decoction of fleſh, its nature is not yet fully known. M. Thouvenel obtained it in the form of down, or in that of ill-formed cryſtals. This chemiſt thinks that it is a perfect neutral ſalt, formed by the vegetable fixed alkali and an acid which has the character of the microcoſmic acid in frugivorous quadrupeds, and the marine in carnivorous animals: but this ſalt ſhould be conſidered as unknown, till a ſufficiently great quantity ſhall have been collected to afford a complete examination, eſpecially by means of the teſts. It is neceſſary to obſerve, that a long troubleſome labour is requiſite to free it of the extractive, gelatinous, and lymphatic matters, which blunt its properties.

Of the Bones of Animals.

The bones are the ſupport of all the other organs of animals, and the baſe upon which all the ſoft parts reſt. Theſe hard parts ought not to be conſidered as paſſive in the animal-œconomy; they are real ſecretory organs, which ſeparate from the blood and other humours a particular ſaline matter, of which they are the depoſition or the reſervoir.

The bones, conſidered in all animals from man down to inſects and worms, differ in their texture, ſolidity, poſition relatively to the muſcles, and probably in their nature. Chemical analyſis has not yet decided this laſt point: but we cannot refuſe to believe that the bones of man and quadrupeds are of a different form from the ſoft and flexible bones of fiſhes, reptiles, and eſpecially the horny ſkeleton of inſects, and likewiſe from the calcareous ſhell of ſhell-worms. The point of view under which we muſt examine animals bones here, does not allow us to inſiſt upon theſe differences which chemiſts have not yet accurately inveſtigated, ſo as to fix the opinion of phyſiologiſts.

The bones of man and quadrupeds, which alone have been hitherto examined by chemiſts, are not earthy matters,

ters, as was formerly imagined; they contain a certain quantity of gelatinous matter diſperſed in the ſmall cavities formed by the ſeparation of the ſolid laminæ, which compoſe their texture; and theſe ſolid laminæ themſelves, which in their inſolubility and conſiſtence ſeem to approximate to earthy matters, have been theſe ſeveral years known to be a true neutral ſalt formed of the phoſphoric acid and lime.

Bones expoſed to the fire with the contact of air, kindle by means of a certain quantity of medullary fat which they contain. If they are diſtilled in a retort, they yield an alkaline phlegm, a fetid empyreumatic oil, and a great deal of concrete volatile alkali. Their coal is compact; it incinerates with very great difficulty; it leaves a white reſiduum, which furniſhes by waſhing with cold water a ſmall quantity of ſoda or natrum.

Hot water next carries off a ſmall quantity of ſelenite. What remains after theſe ablutions is inſoluble in water; it is a calcareous phoſphoric ſalt, which the vitriolic and nitrous acids are ſuſceptible of decompoſing.

The water in which we boil bones, reduced into ſmall pieces or grated down, is mixed with a ſubſtance which gives it viſcidity, and is a true gelatinous matter.

The alkalis are capable of decompoſing the calcareous phoſphoric ſalt, which forms the baſe of the bones. This decompoſition is announced by the Dijon Academicians. They ſay, that they effected it by fuſing a mixture of calcined bones and fixed alkali.

The acids act upon bones, and decompoſe the phoſphoric ſalt which they contain. By means of them Meſſrs Scheele and Gahn, about ſix years ago, extracted from them the phoſphoric acid. Theſe chemiſts at firſt employed the nitrous acid, which completely diſſolved the bones. This acid ſeized upon the lime, with which it formed calcareous nitre, which remains diſſolved at the ſame time with the phoſphoric acid. Into this mixture they poured ſome vitriolic acid, which carried off the lime of the calcareous nitre, and formed ſelenite:

they ſeparated this laſt, which precipitated on account of its inſolubility by filtration: laſtly, they diſtilled in a retort the filtrated liquor, which was a mixture of nitrous and phoſphoric acids; and they obtained this laſt in the ſtate of phoſphoric glaſs. By heating it in a retort with ſome powdered charcoal, they procured phoſphorus much more readily than had been done from the reſiduum of urine. Meſſrs Poulletier de la Salle and Macquer are the firſt who repeated theſe excellent experiments at Paris. Then the Dijon Academicians, Rouelle, Prouſt, and Nicolas, communicated their reſearches and proceſſes. Several other chemiſts examined the different ſolid matters of animals; and among theſe laſt, M. Berniard extracted phoſphoric acid from foſſil bones, from thoſe of the whale, porpoiſe, elk, ox, man, from the teeth of the ſea-cow, the elephant's grinders; and he obſerved that all theſe bones yielded the ſame ſubſtances, and contained the phoſphoric acid in different quantities. See *Phyſical Journal, October* 1781. M. le Marquis de Bullion alſo extracted ſome phoſphoric glaſs from ivory.

The acid of phoſphorus is extracted from bones in the following manner: The bones are calcined to whiteneſs, reduced to a powder, paſſed through a ſearch, mixed in an earthen veſſel with an equal part of oil of vitriol. and a ſufficient quantity of water added, ſo as to make the whole of a milky conſiſtence: the mixture is left to reſt for ſome hours: after the decompoſition is complete, the liquor is put through a double cloth; the precipitate is waſhed with water till this liquor which paſſes through the cloth is taſteleſs, and no longer precipitates lime-water. Then we are certain that the reſiduum contains no more free phoſphoric acid: the water of the different ablutions is evaporated; it gradually depoſites a white matter, which is ſelenite, and which is ſeparated by the filtre; this ſelenite muſt be carefully waſhed in order to get all the phoſphoric acid: theſe filtrations are repeated till the liquor depoſites no more. Then the liquor is evaporated till it put on the conſiſtence of honey or of a ſoft extract; it then acquires a brown colour and a fat appearance. It is put into a crucible, and heated by degrees, till it ceaſe to emit any ſulphureous, as if aromatic, odour, and till it no longer boils. In this ſtate this matter has a ſemivitreous conſiſtence and acid taſte: it attracts humidity from air. If it undergoes a ſtronger heat, it fuſes into a tranſparent glaſs, hard, inſipid, inſoluble, ſhowing no mark of acidity any longer. When we want to obtain phoſphorus from it, we ought not to wait till the reſiduum of the evaporated acid liquor be in this ſtate of inſoluble glaſs, becauſe it then yields it only by means of a ſtrong heat, and much more ſlowly than when it is ſoft and deliqueſcent. It is reduced into phoſphorus by reducing it to powder: mixing it with half its weight of very dry powder of charcoal, it is introduced into a retort of freeſtone, to which a recipient half filled with water is adapted, and pierced with a very ſmall hole, or terminated by a ſyphon, with M. Woulfe's apparatus: a gradual heat is applied, till the retort be of a white heat; then the phoſphorus runs in drops; and the operation continues upon the whole from five to ſeven or eight hours, according to the quantity of matter which we are diſtilling, and the force of heat which the furnace cangive. From ſix pounds of bones twenty ounces, or a little more, of vitreous reſiduum, are obtained; and this reſiduum yields from three to four ounces of very fine phoſphorus, and a few gros of phoſphorus half decompoſed.

It is the caſe here with this product, extracted from bones by the vitriolic acid, as with the reſiduum of the fuſible ſalt of urine decompoſed by the fire. This product is not pure phoſphoric acid, ſince it yields upon the whole only a fifth of its weight of phoſphorus; it appears to contain a certain quantity of calcareous earth, becauſe the ſelenite, which cannot be taken away entirely, is decompoſed by the concentrated phoſphoric acid, and reforms calcareous phoſphoric ſalt, which enters into fuſion by means of the exceſs of vitreſcible acid. Beſides that, the oſſeous phoſphoric glaſs is partly formed of the particular ſubſtance diſcovered by M. Prouſt, which ſeems conſtantly to accompany the phoſphoric acid combined in the humours of animals. This chemiſt has not yet ſhown the proceſs for extracting this ſubſtance from the oſſeous phoſphoric glaſs; but the examinations which he has promiſed of this important ſubject will ſurely indicate this proceſs, and elucidate in a great degree the hiſtory of this product of art. Laſtly, ſome modern chemiſts have thought, that the phoſphoric acid is not contained in bones, and that it is formed by the vitriolic acid employed in its extraction. M. Berniard is at preſent ſtudying to decide this queſtion; and we may expect great ſatisfaction from this chemiſt's inveſtigations.

LECTURE LXIX.

Of the different SUBSTANCES *uſeful in* MEDICINE *or the* ARTS, *which are extracted from different* ANIMALS.

IF we propoſed to give an accurate and complete account of all the ſubſtances which animals furniſh to medicine and the arts, we ſhall have more to ſay upon this ſubject alone than has yet been delivered upon the animal-kingdom, eſpecially if we ſpeak of the different animal-ſubſtances, which empiriciſm or blind credulity formerly introduced into medicine as famous remedies, and which are now happily regarded as entirely uſeleſs. Our deſign is to ſhow only the principal of theſe ſubſtances; thoſe in which chemical and medicinal experience has owned very remarkable virtues, or which are of great uſe in the arts. The number of theſe matters is not very conſiderable; and the moſt part of them is ſo fully known, and ſo excellently handled by medical authors, that we ſhall offer, in a few words, only their principal properties; with ſo much the more reaſon, that they almoſt all relate to the fluid or ſolid ſubſtances of animals, which we have been juſt now examining.

Among the matters which quadrupeds furniſh, we ſhall chooſe caſtor, muſk, and cornu cervi or hartſhorn. Spermaceti, produced by a cetacea, merits a particular examination. Among the products of birds, we ſhall relate the analyſis of eggs; the amphibia, the tortoiſe, frog, and viper, ſhall have a ſeparate article. Ichthyocolla alone among the fiſhes will take up our attention. The claſs of inſects will furniſh a greater number of ſubjects: we ſhall take notice of cantharides, ants, millepedes; honey and wax, reſin, lac, kermes, cochineal, and lapides cancrorum. As for the worms, among which we comprehend the lumbrici, oyſter-ſhells, mother-of-pearl, the bone of the ſound, we ſhall not make any remark about them here; either becauſe ſeveral of theſe ſubſtances have not been analiſed, or becauſe ſome of them entirely reſemble thoſe which we have examined before. Laſtly, we ſhall terminate our examination of the products of the animal-kingdom with coral and coralline. From this ſhort enumeration it is evident, that we paſs over in ſilence a great number of other matters which were formerly employed in medicine: ſuch are, among the reſt, ivory, unicorn, the teeth of the hippopotamus, thoſe of the beaver and wild boar, the bones of the ſtag's heart, elk's foot, bezoar ſtones, civet, the blood of the wild goat, in quadrupeds; the ſwallow's neſt, gooſe's greaſe, peacock's dung, the membrane of the chick's ſtomach, among birds; the toad, among reptiles; the gall and ſtones of the carp, ſerpent's liver, perch-ſtones, the jaws of the pike, among fiſhes; ſilk, ſpider's web, crab's claws, among inſects; laſtly, ſnails and the dentales, among the naked or covered worms. Of all theſe ſubſtances, ſome have only ſuch virtues as exalted imagination has beſtowed upon them; and others are very well ſupplied by thoſe which we have ſelected, and of which we are going to give the particular examination.

Caſtor.

The name of *caſtor* has been given to two bags, ſituated in the inguinal region of the male or female beaver, which contain a matter very odorous, ſoft, and almoſt fluid, when they are recently taken from the animal; but which dry, and put on the conſiſtence of a reſin, through length of time. This ſubſtance has an acrid, bitter, nauſeous taſte: its ſmell is ſtrong, aromatic, and even fetid: it is formed of a coloured reſinous matter, which ſpirit of wine and ether diſſolve; of a mucilage, gelatinous and partly extractive, which water carries off; and a ſalt, which cryſtalliſes in the aqueous ſolution when evaporated, but whoſe nature is as yet a ſecret. The reſin of caſtor, in which all its virtue reſides, ſeems to be very analogous to that of the bile. All the ſubſtance of this animal-product is contained in membranous cells, which riſe from the internal tunic of the bag which contains them. There is no accurate analyſis of caſtor yet: we only know, that it gives a little eſſential oil and concrete volatile alkali to diſtillation; and that by means of ſpirit of wine, ether, and water, the different matters of which it is compoſed are ſeparated.

In medicine, it is employed as a powerful antiſpaſmodic in hyſteric and hypochondriacal fits, and in convulſions which depend upon the ſame affection. The moſt happy and ready effects are frequently produced by it; but it happens ſometimes that it irritates inſtead of calming, according to an unknown diſpoſition of the nervous and ſenſible ſyſtem: it therefore ſhould be given only in a very ſmall quantity at firſt. It has been given with ſucceſs alſo in the epilepſy, tetanus, &c. Its doſe is from a few grains to half a gros in ſubſtance: it is given in the form of boluſes: it is frequently mixed, and almoſt always with advantage, with opium and all the calming or narcotic extracts. Its ſpirituous and etherial tincture is alſo made uſe of, which is preſcribed from a few drops to twenty-four or thirty-ſix grains, in convenient drinks.

Muſk.

MUSK, a ſubſtance known to every body by its ſtrong tenacious ſmell, is contained in a bag ſituated near the umbilical region of a ruminant quadruped analogous to the antelope and kid, and which differs from them ſufficiently to make a particular genus. This matter is ſimilar to caſtor in its chemical properties. It is a reſin, united with a certain quantity of mucilage, bitter extract, and ſalt. It is often adulterated. Its virtues are more exalted than thoſe of caſtor; it is more active; therefore it is employed only in the moſt preſſing caſes. It is given as a powerful antiſpaſmodic in convulſive diſeaſes, in the hydrophobia, &c. It is looked upon, too, as a violent aphdrodiſiac. We ought to be very careful in its uſe, becauſe it frequently excites, inſtead of allaying, nervous diſorders.

Hartſhorn.

HARTSHORN is one of the animal-ſubſtances which is moſt employed in medicine. It is an oſſeous ſubſtance, which differs in no reſpect from bones. It contains abundance of ſoft gelly, very light and nouriſhing, which is extracted from it by boiling it, when reduced into very ſmall pieces, in eight or ten times its weight of water. If it is diſtilled in a retort, it yields a reddiſh and alkaline phlegm called *ſpirit*, an oil more or leſs empyreumatic, and a great quantity of mild volatile alkali. In the operation an enormous quantity of gas, in great part inflammable, is diſengaged. As the volatile ſalt is coloured, it is digeſted in a little ſpirit of wine, which carries off the oil that renders it impure. The charry reſiduum incinerated, contains a little natrum, ſelenite, and a great quantity of calcareous phoſphoric ſalt, which is decompoſed by oil of vitriol, as has been remarked in treating of the bones. The ſpirit and ſalt of hartſhorn are employed in medicine as very good antiſpaſmodics. The former, ſaturated with the acid ſalt of amber, forms the liquor cornu cervi ſuccinatus. Oil of hartſhorn, rectified with a gentle heat, becomes very white, odorous, very volatile, and almoſt as inflammable as ether: it is known by the name of *Dippel's animal-oil*, a German chemiſt, who firſt prepared it. Formerly a great number of rectifications were employed to obtain the oil very white and fluid. It is ſince diſcovered, that two or three ſuffice, provided they have been done with the precaution, 1. Of introducing the oil to be rectified into a retort by means of a long funnel, ſo that the neck of the veſſel may be very clean; for a ſingle drop of coloured oil is ſufficient to communicate colour to all that is diſtilling. 2. Of taking only the firſt moſt volatile and white portions: Meſſrs Model and Baumé made theſe obſervations. M. Rouelle has given alſo a very good proceſs for obtaining this oil; it conſiſts in diſtilling it with water. As it is only the moſt volatile and moſt really ethereal portion contained even in the oil of the firſt diſtillation which the heat of boiling water can raiſe, we are certain by this means of having only the moſt ſubtile and penetrating portion. This oil has a briſk ſmell, and a ſingular lightneſs and volatility; it preſents all the characters of vegetable eſſential oils; it ſeems to differ from them only in containing volatile alkali, ſince it turns the ſyrup of violets green, according to M. Parmentier.

This oil is employed in drops in nervous affections, epilepſy, &c.

Spermaceti.

Spermaceti is an oily, concrete, cryſtalline, ſemitranſparent matter, of a particular wild ſmell, which is obtained from the cavity of the cranium of the whale, and which is purified by liquefaction and ſeparation ſrom another fluid inconcreſcible oil, which is mixed with it. This ſubſtance preſents very ſingular chemical properties, which aſſimilate it on the one ſide to the fat oils, and on the other to the eſſential oils.

Spermaceti, heated with the contact of air, kindles and burns uniformly, without emitting a diſagreeable ſmell; very fine candles on that account are made with it in the countries where it is manufactured, at Bayonne, Saint-Jean de Luz, &c.

If it is diſtilled in a naked fire, it gives no acid phlegm like the fat oils, according to M. Thouvenel; but it all paſſes over almoſt quite unaltered into the recipient when it begins to boil, and it leaves in the retort a charry mark. By repeating this operation, it loſes its ſolid form, and remains fluid, without being more volatile.

Spermaceti expoſed to hot air turns yellow, and becomes rancid, but not ſo eaſily as the other concrete fat oils. The water in which it is boiled yields by evaporation only a ſmall mucoſo-unctuous reſiduum.

The cauſtic alkali diſſolves ſpermaceti, and forms with it a ſoap, which gradually acquires ſolidity till it become friable.

The nitrous and marine acids have no action upon it. The concentrated vitriolic acid diſſolves it, and alters its colour. This ſolution is precipitated by water like oil of camphor.

Spermaceti unites with ſulphur like the fat oils.

The fat and eſſential oils diſſolve it by means of heat: hot ſpirit of wine alſo diſſolves it, and allows it to precipitate by cooling. Ether diſſolves it in the cold, or by the heat of the hand alone.

Might ſpermaceti be to the fat oils what camphor is to the eſſential?

Medicine formerly made very extenſive uſe of this ſubſtance; a great number of properties was aſcribed to it. It was uſed eſpecially in catarrhal caſes, eroſions, ulcers of the lungs, kidneys, &c. At preſent it is ſeldom employed except as an emollient, and even in a ſmall quantity, as it is found to oppreſs the ſtomach, and to occaſion nauſea and vomiting.

Of Eggs.

THE eggs of birds, and in particular thoſe of hens, are compoſed, 1. of an oſſeous ſhell, which contains a gelly and ſome calcareous phoſphoric ſalt, demonſtrated by M. Bernard; 2. of a membranous pellicle, placed below the ſhell, which ſeems to be a texture of fibrous matter; 3. of the white; 4. of the yolk contained and ſuſpended in the middle of the white. Upon this laſt ſubſtance the germ is ſupported.

The white of an egg is abſolutely ſimilar to the lymph of the blood: it is viſcous, gluey, turns the ſyrup of violets green, and contains free fixed mineral alkali. Expoſed to a gentle heat, it coagulates into a white opaque maſs, which emits an hepatic ſmell and gas. This white, coagulated and dried in a balneum mariæ, yields an inſipid phlegm, which putrefies, and acquires the hardneſs and reddiſh tranſparency of horn. Diſtilled in a retort, it yields concrete volatile alkali and empyreumatic oil: its coal contains a little mineral alkali. The white of an egg, expoſed to the air in ſmall layers, dries rather than corrupts, and forms a ſort of tranſparent varniſh. It diſſolves in water in all proportions. The acids coagulate it: if this coagulum, diſſolved in water, is filtrated, the fluid which paſſes over yields by evaporation the neutral ſalt, which ſhould be formed with the acid employed and the fixed mineral alkali contained in this liquor. Spirit of wine alſo coagulates the white of an egg.

The yolk is formed in great part of a lymphatic matter, but is mixed with a certain quantity of ſweet oil; ſo that this mixture diſſolves in water, and forms a kind of animal emulſion. If it is expoſed to the fire, it turns into a maſs leſs ſolid than the white; when it is dry, it becomes ſomewhat ſofter, from the diſengagement of its oil which iſſues out at its ſurface. If in this ſtate it is ſubmitted to the preſs, this oil is obtained, which is ſweet and fat, ſmelling and taſting ſomewhat of roaſt meat, or it is empyreumatic.

The yolk of an egg diſtilled after the extraction of the oil, yields the ſame products as all animal matters.

The acids and ſpirit of wine coagulate it. The ſweet oil which it contains eſtabliſhes a ſtriking analogy between the eggs of animals and the grain of vegetables, as theſe laſt alſo contain an oil, which is at the ſame time covered with a mucilage, and reduced to the ſtate of an emulſion.

Eggs are of very extenſive uſe as an aliment. Its different parts are uſed in pharmacy and medicine. The ſhell calcined is uſed as an abſorbent. The oil of an egg is an emollient: it is uſed externally in burns, chaps, &c. The yolk of an egg renders oils ſoluble in water, and forms lohochs. It is triturated with reſins. The whites of eggs are employed with ſucceſs in pharmacy and butteries, to clarify the juices of plants, weak milk, ſyrups, liquors, &c. It is alſo employed to preſerve the ſurface of tables, upon which it forms a tranſparent varniſh.

Of the Tortoiſe, Frog, and Viper.

THESE three animals are employed in medicine: broths are made with their fleſh and their bones, to which particular virtues are aſcribed. It would indeed appear that the zoophyte animals, whoſe humours are more attenuated than thoſe of moſt quadrupeds, whoſe parts have in general a ſtronger and quite particular ſmell, and appear to contain more ſaline matter, as they furniſh much volatile alkali upon diſtilling them with a gentle heat, after they have been triturated with oil of tartar; theſe animals, I ſay, ſeem to enjoy more powerful and more numerous virtues. However, many phyſicians doubt of their energy, and aſcribe them to the other animals. In ſpite of this opinion, it is ſtill a practice to preſcribe broths of tortoiſe and frog fleſh, in languid habits, conſumptions without any apparent cauſe, to convaleſcents from acute diſeaſes; and good effects are experienced from them frequently. It ſeems that their decoctions are more nouriſhing, more light, and endued at the ſame time with a certain activity, which their ſtrong ſmell and particular taſte ſufficiently demonſtrate.

Vipers are accounted more active. The ancients boaſted greatly of their virtues in diſeaſes of the ſkin, breaſt, chronic affections, where the lymph is vitiated. We cannot be hindered from believing, that their broths are better reſtoratives than aliments, and ought to produce depurations by the ſkin, by means of their exalted ſpiritus rector. They are alſo adminiſtered entire, and as aliments, and with ſucceſs in the ſame diſeaſes.

The chemical analyſis of theſe animals demonſtrated to M. Thouvenel a gelly lighter or heavier, conſiſtent or viſcous; an acrid extract, bitter and deliqueſcent; a concreſcible aluminous matter; an ammoniacal ſalt, and an oily ſubſtance of a particular taſte and ſmell, ſometimes ſoluble in ſpirit of wine, &c. See this author's Memoirs upon the Medicinal Animal Subſtances, p. 6. to 21.

Ichthyocolla.

ICHTHYOCOLLA, or fiſh-glue, is a ſubſtance in part gelatinous and in part fibrous, which is prepared by rolling the membranes which form the vas natatorius of the ſturgeon, and of ſeveral other fiſhes, and by drying them in the air, after forming them into a cord twiſted into a heart. This matter gives a viſcid gelly by ebullition in water. When it is macerated ſome time in this fluid, it cannot be folded and extended into a kind of membrane. It is never brittle, as the glues properly ſo called; but it is flexible, on account of its fibrous and elaſtic texture. A kind of it is alſo prepared by the decoction of the ſkin and inteſtines of fiſhes; but it has not the ſame properties in the arts. Ichthyocolla yields all the products of other animal ſubſtances. It may be employed in medicine as an emollient in diſeaſes of the throat, inteſtines, &c.; but ſeveral other vegetable ſubſtances are generally preferred which enjoy the ſame properties. In the arts, it is uſed to clarify liquors, wine, coffee, &c. It forms a filtre, which carries from their bottom up to their ſurface the ſtrange matters which alter their tranſparency.

LECTURE LXX.

CANTHARIDES, ANTS, MILLEPEDES.

INSECTS have alſo been very little examined by chemiſts: however, the ſingularities which ſome have preſented in their anlyſis, ſhow that inquiries of this kind will be intereſting to medicine and the arts. We are going to give here the reſult of the experiments made upon three inſects; two of which are employed in medicine, and the other preſents chemical facts, too intereſting to be paſſed over in ſilence.

1. Spaniſh flies, or cantharides, a remedy ſo important on account of its corroſive and epiſpaſtic qualities, are formed, according to M. Thouvenel, 1. of a parenchyma, whoſe nature has not been demonſtrated, and which makes the half of the weight of theſe inſects dried; 2. of three gros in the ounce of a reddiſh yellow extractive matter, very bitter, which yields an acid to diſtillation; 3. of twelve grains in the ounce of a yellow and waxen matter, to which theſe animals owe their golden yellow colour; 4. of ſixty grains of an oily green ſubſtance, analogous to wax, of an acrid taſte, in which principally the odour of cantharides reſides. To diſtillation this ſubſtance yields a very pungent acid, and a concrete oil like wax. Water diſſolves the extract;

tract, the yellow oil, and even a little of the green oil; but ether alone attacks this ſubſtance, and may be employed with ſucceſs to ſeparate it from the others. Upon this kind of green wax depends the virtue of the cantharides. This laſt ſubſtance is extracted at the ſame time with the extractive matter, and a tincture is formed very copious in theſe inſects, by employing a mixture of equal parts of water and ſpirit of wine. By diſtilling this mixt tincture, a ſpirit of wine is extracted, which preſerves a ſlight colour of the cantharides; and the different matters which it kept in ſolution, ſeparate from one another as the evaporation proceeds.

2. The ants have been analyſed by Meſſrs Margraaf and Thouvenel. Theſe chemiſts found that they contained a particular acid, a fat oil, and an extractive matter. The ſecond puſhed his inquiries much farther. Upon diſtilling theſe inſects with water, the fluid which was obtained is but ſlightly acid. With a view of collecting this ſaline principle, M. Thouvenel extended pieces of linen impregnated with oil of tartar upon ants with the ſkins taken off. The ants emitted their acid, and the odorous principle of the ſame nature, which they emit in ſo great abundance as to ſaturate the fixed alkali ſpread upon the cloth. The ley of theſe ſalts evaporated yielded a neutral ſalt, cryſtalliſed in flat parallelograms, or in priſmatic columns, not deliqueſcent, whoſe acid appeared to this chemiſt to have all the characters of that of the microcoſmic or fuſible ſalt. Spirit of wine digeſted upon ants extracted a little eſſential oil from them, which conſtitutes with this fluid the ſpirit of magnanimity. If theſe inſects are boiled in water, and then preſſed through cloth, a fat oil is got, which amounts to thirteen gros in the pound. This oil is of a greeniſh yellow; it congeals in a temperature much leſs cool than that in which oil of olives congeals, and it is very analogous to wax. The water of the decoction evaporated, yields a reddiſh brown extract of a fetid ſmell, acidulous, and like

cheeſe; of a bitter, nauſeous, and acid taſte. This extract ſeparates into two ſubſtances by the ſucceſſive application of water and ſpirit of wine. The parenchyma of ants, deprived of theſe different ſubſtances, amounts to three ounces two gros in the pound.

3. The palmers, millepedes, aſelli, porcelli, oniſci, &c. ſhowed to M. Thouvenel ſome differences in their analyſis. Diſtilled in a balneum mariæ without addition, they yielded an inſipid alkaline phlegm, ſometimes effervеſcing with acids, and turning ſyrup of violets green. In this operation they loſt five-eighths of their weight; then treated by water and ſpirit of wine, they furniſhed in the ounce two gros of ſoluble matter, of which more than two-thirds were extractive matter, and the reſt an oily or waxen ſubſtance. Theſe two ſubſtances are ſeparated by ether, which diſſolves the laſt without touching the extract. Theſe matters differ from thoſe of cantharides and ants, in their yielding more concrete volatile alkali, and no acid in their diſtillation. M. Thouvenel upon this ſubject has obſerved, that in inſects the millepedes ſeem to be to the cantharides and ants, what the reptiles are relatively to quadrupeds.

As to the neutral ſalts contained in inſects, they are in greater quantity, and very difficult of extraction. M. Thouvenel ſays, that the millipedes and earth-worms, lumbrici, conſtantly yielded marine ſalt with earthy and vegetable alkaline baſe; whilſt in ants and cantharides theſe two baſes, the firſt of which always ſeemed to him the moſt abundant, are united with an acid, which has the character of the microcoſmic acid. It is neceſſary to obſerve that this chemiſt has given in his diſſertation neither the means of extracting theſe ſalts, nor the proceſſes which he employed in the inveſtigation of their nature.

They are ſeldom employed in medicine, except cantharides and millepedes. Theſe laſt appear to act only as ſtimulants and ſlight diuretics; and, from the experiments of M. Thouvenel, they ought not to be employed in a ſtronger doſe than what is generally employed.

The expreſſed juice of forty or fifty living millepedes given in an emollient drink, or mixed with the juice of certain aperient plants, may be employed with ſucceſs in the jaundice, ſerous maladies, *à ſeroſa colluvie*, milky collections, &c. As to the cantharides, it is one of the moſt powerful medicines which medicine poſſeſſes. M. Thouvenel himſelf experienced the effects of the green wax matter, in which the virtue of theſe inſects reſides: applied to the ſkin in the doſe of nine grains, it raiſed a bliſter full of ſeroſity, as the cantharides in powder do. But what is moſt valuable in theſe experiments upon this powerful remedy, is what this phyſician obſerved from the effects of the ſpirituous tincture of the flies. He employed it with great ſucceſs externally, in the doſe of two gros to two ounces and a half, in rheumatic and ſciatic pains, irregular gout. It heats the parts, accelerates the motion of circulation, excites the evacuation by ſweat, urine, ſtool, according to the parts upon which it is applied. He alſo relates ſome good effects from its internal uſe by foreign phyſicians. But young phyſicians ought to be very cautious in the internal uſe of this medicine; it has been ſeen to occaſion frettings of the ſkin, inflammations, ſpittings of blood, pains in the kidneys, bladder, dyſuries, &c, Vid. *Diſſert. cit. M. Thouvenel*, p. 46.—50.

Of the Honey and Wax.

THESE two matters, prepared by the bees, ſeem to belong to the vegetable kingdom, as theſe inſects go to collect the firſt in the nectaria of the flowers, and the ſecond in the anthera of their ſtamina. However, they have undergone a particular elaboration; and beſides, as they are extracted after the labour of the bees, their properties ſhould be examined in the hiſtory of inſects.

Honey is a matter perfectly ſimilar to the ſaccharine juices, which we have examined in vegetables. It has a white or yellow colour, a ſoft and granulated conſiſtence, a ſaccharine and aromatic taſte. A true ſugar may be ex-

extracted with ſpirit of wine and water, by means of certain manipulations. It yields an acid phlegm and an oil to the retort; and its coal is rare and ſpongy, like that of the mucilages of plants. The nitrous acid extracts from it an acid entirely analogous to that of ſugar. It is very ſoluble in water; it forms a ſyrup, and it paſſes as ſugar does to the ſpirituous fermentation. It is a very good aliment, and an emollient, pectoral, and ſlightly aperient medicine. It is given diſſolved in water and mixed with vinegar, called *oxymel;* it is often combined with ſome acrid plants, as when it forms the oxymel ſcilliticum, colchicum. It forms the baſe of ſeveral medicines, which bear its name, as mel-roſarum, roſe-water, mel mercuriale, &c.

Wax is a concrete oily juice, analogous to the ſolid fat oils, ſuch as the butter of Cacao; and ſtill more ſo to the royal pigment of China. Although it cannot be doubted that this ſubſtance comes from the ſtamina of flowers, it is, however, demonſtrated, that it receives in the body of the animal a particular elaboration; ſince, according to the eſſays of M. de Reaumur, a flexible powder cannot be made with the powder of the antheræ. The wax, which compoſes the cells of the bees, is yellow, of an inſipid taſte; it is whitened by expoſure to the dew and the air, after it has been reduced into minute laminæ; it ſoftens when heated with a gentle fire, fuſes, and forms a tranſparent oily fluid; it becomes ſolid and opaque by cooling. When it is heated with the contact of air, it kindles as ſoon as it is volatiliſed; ſuch is the effect produced by the wick of candles. If it is diſtilled in a retort, it yields an acid phlegm of a ſtrong pungent ſmell, an oil at firſt fluid, which afterwards fixes in the receiver, and has the conſiſtence of butter; it leaves only a very ſmall quantity of coal, very difficult of incineration. By ſeveral times rectifying the butter of wax, it becomes fluid and volatile. Wax is not alterable by the air; it becomes coloured by it in a certain time; it diſſolves in the oils, to which it gives conſiſtence. By melting it in theſe fluids with a gentle heat, it forms medicines, called *cerates.* Spirit of wine has no action upon wax. The acids blacken it; the alkalis combine with it, and convert it into a ſoapy ſtate.

Wax is employed in a great number of arts; it is employed in pharmacy to make liniments, ointments, and plaſters.

Reſin Lac.

THE improper name of gum lac has been given to a reſinous ſubſtance of a deep red, which is depoſited upon the branches of trees by a kind of ant particular to the Eaſt Indies. This ſubſtance appeared to M. Geoffroy, Memoirs of the Academy 1714, a kind of hive in which the ants depoſite their eggs. Indeed, if the lac is bruiſed into ſticks, it is found filled with ſmall cavities or regular cells, in which ſmall oblong bodies are placed, which Geoffroy conſidered as the embryos of the ants. This chemiſt thinks that the lac owes its colour to this animal matter. He conſiders this laſt as a true wax: however, its dryneſs, the aromatic ſmell which it emits upon burning, and its ſolubility in ſpirit of wine, ſeem to approximate it to the reſins; it yields to diſtillation a kind of butter, according to the ſame author. In commerce, we diſtinguiſh lac in ſticks, lac in grains, and flat lac. It muſt be obſerved, that many other colouring ſubſtances, and in particular the red animal or vegetable feculæ, prepared in a particular manner, are called in dyeing by the name of *lacs.* Reſin lac is uſed in the Levant for painting cloths and ſkins. It makes the baſe of ſealing-wax. A tincture of it is made with ſpiritus cochleariæ. It enters the troches of karabé, dentifrice powders and opiates, ſmelling paſtes, &c.

Of Kermes and Cochineal.

KERMES, coccus inſectorius, was conſidered by the firſt naturaliſts as a tubercle or an excreſcence of plants. More accurate obſervation has ſhown, that it is the female

male of an inſect, ranked among the hemipteræ by M. Geoffroy. This female inſect fixes to the leaves of the green oak; after having been fecundated, it turns larger, grows up, and ſoon aſſumes the form of an inſect; it repreſents a round brown ſhell, under which are comprehended eggs in very great number. This ſhell was formerly employed in dyeing; its uſe was given up after cochineal was known. Kermes preſents the ſame chemical properties as this laſt.

There was the ſame miſtake about cochineal as about kermes: it was a long time conſidered as a grain. Father Plumier is one of the firſt who diſcovered this error. Indeed this ſubſtance is the female of an hemipterous inſect, which differs from the kermes in this, that it preſerves its form although fixed upon plants. Cochineal employed in dyeing grows upon the opuntia, the Indian fig-tree. It is cultivated in great quantities in South America. Geoffroy, who analyſed it, found in it the ſame principles as in the kermes; he got from it ſome volatile alkali. The form of this inſect may be ſeen by macerating this inſect in water. Cochineal is employed to make carmine, and in dyeing. A crimſon or ſcarlet colour is extracted from it, according to the manner in which it is uſed. As it is an extractive colouring matter, it cannot be fixed upon the ſubſtances to be dyed without the aſſiſtance of ſome active ſubſtance. It acts eaſily upon wool, and dyes it ſcarlet by means of the ſolution of tin in aqua regia, which decompoſes the colouring extract, and ſingularly exalts the colour. This colour could not be given to ſilk before the diſcovery of M. Macquer. This chemiſt found the method of fixing it upon this ſubſtance, by impregnating the ſilk with the ſolution of tin before plunging it into the bath of cochineal, inſtead of mixing this ſolution in the bath, as is done to wool.

Of Crab's Eyes and Coral.

THE ſtony concretions, falſely called *crab's eyes, occuli*

cran-

cancrorum, are found two in number in the interior and inferior part of the ſtomach of theſe inſects. They are round, convex on one ſide, concave on the other, and ſituated between the two membranes of their ſtomach. As they are found only when the crabs are changing their ſkin and ſtomach, and as they are gradually deſtroyed in proportion as their new covering acquires conſiſtence, it is believed with great probability, that they ſerve for the reproduction of the calcareous ſubſtance which makes the baſe of their ſcales.

Theſe ſtones have no taſte; and contain a ſmall quantity of gelatinous matter. They are prepared by waſhing them ſeveral times, and porphyriſing them with a little water to reduce them into a ſoft paſte, which are moulded into troches and dried. The water employed in waſhing carries off what animal gelly theſe ſtones contain, and no more than the earthy ſubſtance remains. When prepared in this way, they make a briſk efferveſcence with all acids, and are abſolutely of the ſame nature with chalk. They have no other virtue than that of abſorbing acidities in the primæ viæ. From the very doubtful opinions about all theſe animal ſubſtances in general, they have been accounted aperient, diuretic, and even cordial remedies.

Coral is quite of a ſimilar nature; it is a kind of calcareous white, roſy, or red ramification, which forms the baſe of the habitation of the polypi. It is prepared in the ſame way as crab's eyes; it enters the confection alkermes, *la poudre de guttete*, troches of karabé. Numberleſs properties are aſcribed to it; but it has abſolutely no virtue but that of a pure abſorbent, unleſs combined with the acids. It is frequently employed, juſt as crab's eyes, in the ſtate of a neutral ſalt, formed with vinegar or citron juice, as an aperient, diuretic, &c.

Of Coralline.

Coralline, called *ſea-moſs*, is a habitation particular to the polypi. It yields to the retort the ſame principles as animal ſubſtances; it has a ſaline taſte, bitter and diſagreeable; it is ſucceſsfully employed as a vermifuge; it is given in powder in the doſe of twenty-four grains to children, and increaſed to two gros or more to adults. An anthelmintic ſyrup is made of it; it enters the compoſiton of the worm-powder.

Of the Chemical Analyſis of Animals and Vegetables.

If naturaliſts and anatomiſts have found very great analogies between the ſtructure and functions of vegetables and animals, with a view of uniting theſe two claſſes of bodies into one kingdom alone, called *organic;* chemiſts have not found leſs ſtriking ones between theſe ſubſtances in the nature of their principles, and their reſearches are proper to confirm the analogies which approximate the nature of theſe bodies to each other. In fact, upon comparing the properties of the ſubſtances which analyſis demonſtrates in the vegetable and animal kingdoms, ſtriking relations are to be found. The mucilages, extracts, ſpiritus rector, ſaccharine matter, ſweet and eſſential oils, reſins, and colouring parts, are found in both kindoms: the fermenting property is alſo found in them, and theſe two claſſes of bodies contain matters equally ſuſceptible of paſſing to the ſpirituous, acid, and putrefactive fermentations. It is unneceſſary to give proofs of this aſſertion; they are to be found in the hiſtory of each of the ſubſtances of theſe two kingdoms, which we have examined one after the other: but it is neceſſary to fix the differences which diſtinguiſh their products.

It is a long time ſince phyſicians were convinced that animals procured from vegetables the moſt part of the matter proper to make up their ſubſtance; but the fluids of the firſt being expoſed to more various and more rapid motions than thoſe of vegetables, it is eaſy to conceive that they ought to be ſuſceptible of greater alteration, and that their combinations are more numerous. Indeed the mucilages of animals are more attenuated; the extracts are found only in ſmall quantity; the ſpiritus rector is more penetrating, more active, volatile, and tenacious; the reſins are found only in a few individuals; their colouring parts are more fine and alterable; laſtly, they contain ſaline matters of a quite different nature; and the lymphatic fluid, concreſcible by heat, juſt like the fibrous ſubſtance concreſcible by ſimple repoſe, are two new ſubſtances, owing to the motion from animal life, to which nothing has been found analogous in the vegetable kingdom, although the glutinous matter ſeems to produce ſome reſemblance between them.

From theſe obſervations it follows, that the phenomena which animal ſubſtances preſent in chemical operations, ſhould differ from thoſe which vegetable ſubſtances preſent when treated in the ſame way. On this account, the former yield in general to the retort a great quantity of volatile alkali, fetid oils, a coal of difficult incineration; and, eſpecially, they are much more alterable by heat, repoſe, and humidity.

Of the Putrefaction of Animal Subſtances.

Although vegetable ſubſtances be ſuſceptible of being decompoſed and entirely deſtroyed by the putrid fermentation, as we have related, they are however very far from being ſo proper to undergo this inteſtine motion as animal matters. The putrefaction of theſe laſt is much more rapid, and its phenomena are different: all the fluid and ſolid parts of animals are equally expoſed to it, whilſt ſeveral vegetable matters ſeem to be exempt from it, or at leaſt to undergo it with great difficulty and ſlowneſs.

The putrefaction of animals, which we muſt conſider with Boerhaave as a true fermentation, is one of the moſt important phenomena, and at the ſame time very difficult to be underſtood.

All the works of the philoſophers, from Bacon of Verulam, who had fully felt the importance of the inquiries upon this ſubject, down to our days, have elucidated only a few points, and hinted at the general phenomena preſented by putrefying ſubſtances. Becher, Hales, Stahl, Drs Pringle and Macbride, Gaber, Baumé, the author of the eſſays upon putrefaction, and thoſe of the diſſertations upon antiſeptics, preſented with the prize 1767 by the Dijon academy, have obſerved and carefully deſcribed the facts which the putrid alteration exhibits: but it will be ſeen by the relation we are going to give, that a great number of experiments ſtill remains to be made, to underſtand fully the phenomena of this natural operation.

Every fluid or ſoft ſubſtance, extracted from the body of an animal, expoſed to the air at a temperature of ten degrees or above it, ſuffers more or leſs rapidly the following alterations. Its colour turns pale; its conſiſtence diminiſhes: if it is a ſolid part like meat, it ſoftens, and allows a ſeroſity to iſſue out, whoſe colour very ſoon alters: its texture is relaxed and diſorganiſed; its ſmell becomes diſagreeable; it gradually thickens and diminiſhes in ſize; its ſmell is exalted, and becomes alkaline. In this ſtate, if it is contained in a cloſe veſſel, the progreſs of the putrefaction ſeems to relent; only an alkaline and pungent ſmell is felt. The ſubſtance effervefces with the acids, and turns the ſyrup of violets green: but by opening a communication with the air, the urinous exhalation is diſſipated, and, with a kind of impetuoſity, a particular putrid inſupportable ſmell is emitted, which continues a long time, diffuſes itſelf every where, affects animal bodies as a ferment capable of changing their fluids. This ſmell is corrected, and as if ſtopt, by the volatile alkali. When this laſt ſubſtance is volatiliſed, putrefaction turns active again, the putrefying maſs ſwells preſently, the colour alters, the fibrous texture of the fleſh is almoſt no longer diſtinguiſhable; it is changed into a ſoft brown or yellow matter; its ſmell is nauſeous, and very active upon the bodies of animals. This odorous principle gradually loſes its force: the fluid portion of the fleſh acquires a ſort of conſiſtence; its colour deepens, and it finiſhes by being reduced into to a friable matter, half dry and a little deliqueſcent; which being rubbed between the fingers, is reduced into a groſs powder like earth. Such is the laſt ſtate which terminates the putrefaction of animal ſubſtances: they take a longer or ſhorter time in arriving at this point. Eighteen months, two and even three years, ſcarcely ſuffice for the entire deſtruction of animal bodies when expoſed to the air; nor has the total deſtruction of dead bodies interred, relatively to the time which elapſes before this change takes place, been yet accurately determined.

From this relation it follows, 1. That the conditions proper for evolving and ſupporting the putrefaction of animal matters are, the contact of the air, heat, humidity, and repoſe, or the inertia of bodies: 2. That the volatile alkali is leſs a product of putrefaction than a matter diſengaged, like the oils, during this natural operation, as it exiſts only for a certain time, beyond and within which it never appears: 3. That putrefaction, effected by an inteſtine motion proper to organiſed ſubſtances, may be compared to the action of the fire, as M. Godard has remarked; and may be conſidered as a ſpontaneous decompoſition, as M. Baumé has thought; and that it differs from both only in its ſlowneſs: 4. That in this operation of nature, the immediate principles of animals act upon one another by means of the water which favour their contact, and of the heat which the inteſtine motion produces; that thus the volatile matters are gradually diſſipated in the order of their volatility, and that nothing more remains after putrefaction, except an inſipid, as if earthy, reſiduum: 5. That the putrid exhalation, ſo well characteriſed and diſtinguiſhed by the olfactory nerves, and whoſe action is ſo ſtrong upon the animal œconomy, ſhould be conſidered as the true product of putrefaction, as this exhalation conſtantly exiſts in all ſubſtances which are putrefying, and throughout the whole time of putrefaction; ſince it is proper to this operation, and is found in no other natural phenomenon:

laſtly, As it evolves the putrefactive motion in all animal bodies which are expoſed to its action. As to the nature of this ſubſtance, it is particularly this point which is ſo incompletely underſtood, and requires a farther inveſtigation. What we know of it, ſhows us that it is extremely volatile, attenuated, penetrating; that pure air, water in great quantity, and the acid gaſes, are ſuſceptible of moderating its effects. Altho' it is no miſtake to confound it with the fixed air, which is diſengaged in great quantity from putrefying ſubſtances, to the diſengagement of which Dr Macbride entirely attributed the cauſe of this natural phenomenon; although we ought no longer to compare it either with inflammable gas diſengaged from putreſcent bodies, or to the luminous matter which ſhines at the ſurface of the putrefying ſolids of animals, and which makes theſe ſubſtances appear as ſo many phoſphori; we cannot, however, be hindered from believing, that it has ſome very direct relation with theſe ſubſtances, as it conſtantly accompanies them, and is as volatile, as ſubtile, as they, and as it acts with ſo much energy upon the organs of animals.

We may, with M. de Boiſſieu, diſtinguiſh four ſtages in the putrid fermentation of animal-ſubſtances. The firſt, called by this phyſician a *tendency to putrefaction*, conſiſts in a ſmall alteration, which is manifeſted by an inſipid or very ſlightly muſty ſmell, and in the ſoftening of theſe ſubſtances. The ſecond ſtage, that of commencing putrefaction, is ſometimes indicated by marks of acidity. The ſubſtances which are ſubject to it loſe their weight, aſſume a fetid ſmell, are ſoftened, and allow the ſeroſity to get free when they are in cloſe veſſels; or they dry, and put on a deep colour, if they are expoſed to the free air. In the third ſtage, or advanced putrefaction, the putreſcent matters emit an alkaline ſmell, mixed with the putrid and nauſeous odour: they become as if diſſolved; their colour alters more and more; and at the ſame time they loſe their weight and volume. Laſtly, the fourth degree, that of complete putrefaction, manifeſts itſelf by the entire diſſipation of the volatile alkali, of which no traces remain: the fetid odour loſes its force; the volume and the weight of the putrefied ſubſtances are conſiderably diminiſhed; a gelatinous mucoſity ſeparates; they gradually dry; and are at laſt reduced to an earthy and friable ſubſtance.

Such are the general phenomena which are obſerved in the putrefaction of animal-ſubſtances; but they are far from being the ſame in all putreſcent ſubſtances. There is at firſt a great diſtinction to be made between the putrefaction of the parts of animals when alive and that of their organs when dead. The motion which exiſts in the firſt, ſingularly modifies the phenomena of this alteration; and phyſicians have frequent opportunities of ſeeing the differences which exiſt between theſe two ſtates with regard to putrefaction. Beſides that, every humour, every ſolid part, ſeparated from a dead animal, has alſo its proper manner of putrefying: the muſcular, membranous, or parenchymatous, and more or leſs compact texture of the organs; the oily, the mucilaginous, or lymphatic nature of the humours; their conſiſtence; their ſtate, relative to that of the animal which produced them; influence the putrefactive motion, and modify it in a thouſand ways, which are perhaps inappretiable. Laſtly, How ſhall we enter into a diſcuſſion of the ſtate of the air, its temperature, elaſticity, weight, dryneſs, or humidity of the expoſure of the putrefying ſubſtance in different places, even of the form of the veſſels which contain it? circumſtances, all of which produce alteration in the phenomena of ſpontaneous putrefaction. It muſt therefore be agreed, that the hiſtory of animal-putrefaction is only begun, and that the inveſtigations and experiments of the phyſicians and chemiſts of ſeveral ages, all united, are requiſite to render this ſubject complete.

FINIS.

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